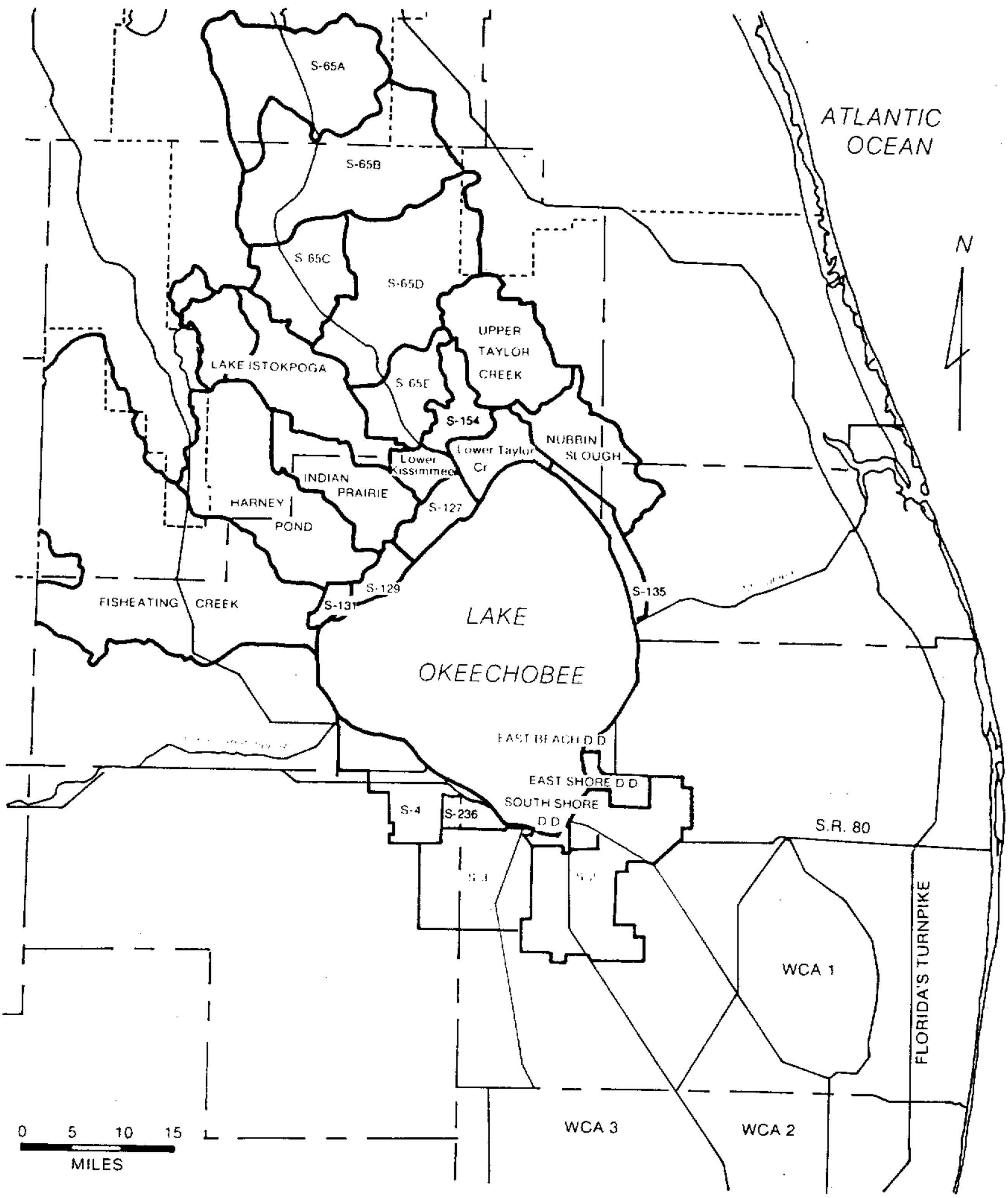
WATER QUALITY MANAGEMENT PLAN FOR THE S-2 AND S-3 DRAINAGE BASINS IN THE EVERGLADES AGRICULTURAL AREA

March 1983



WATER QUALITY MANAGEMENT PLAN FOR THE S-2 AND S-3 DRAINAGE BASINS IN THE EVERGLADES AGRICULTURAL AREA

PREPARED BY
RESOURCE PLANNING DEPARTMENT AND
SPECIAL PROJECTS DIVISION
SOUTH FLORIDA WATER MANAGEMENT DISTRICT
WEST PALM BEACH, FLORIDA

MARCH 1983

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ABSTRACT

In the Executive Summary, Water Quality Management Strategy for Lake Okeechobee, December 1981, a wide range of alternatives for reducing nutrient loading to Lake Okeechobee from its drainage basins were evaluated. These included regional and sub-regional storage, on-site storage and other Best Management Practices (BMPs), conventional and advanced (reverse osmosis) treatment plants, and diversions to other receiving waters. Based on an analysis of costs, nutrient removal effectiveness, and impacts on water resources and other factors, the Taylor Creek/Nubbin Slough Basin (S-191) and the S-2 and S-3 basins in the Everglades Agricultural Area (EAA) were targeted for immediate action under the initial phase of the strategy. The preferred alternative proposed for the Taylor Creek/Nubbin Slough basin was on-site management through the implementation of Best Management Practices (BMPs). In the EAA, regional storage of runoff diverted from the S-2 and S-3 basins to the Holeyland tract, with water recycling capability, was the preferred alternative.

The Strategy was accepted by the Governing Board in December 1981 and submitted to DER for review and approval. After an extensive review by some 30 plus agencies and groups over an approximate six-month period, the DER issued a six-month extension to the TOP (until January 10, 1983) in July 1982 in order to address concerns of the state. These concerns were enumerated in a letter from DER to the District dated June 15, 1982, in which the Department indicated the Strategy was conceptually favorable.

To address these concerns, the District prepared two reports: (1) "Taylor Creek Headwaters Project, Phase 1 Report; Water Quality," and (2) "Water Quality Management Plan for S-2 and S-3 Drainage Basins in the Everglades Agricultural Area." An "Executive Summary Addendum" summarizing the conclusions and recommendations of these reports was prepared and was presented and approved at the November 9 and 10, 1982 Governing Board meetings. The documents were subsequently transmitted to DER for review and approval. Since major policy issues are involved, DER has extended the expiration date of the Lake Okeechobee TOP to May 15, 1983 in order to allow time for the Governor and Cabinet to consider the land use and land exchange issues pertaining to the Holeyland and Rotenberger project proposals. Further, there were several requests for a cost-benefit study of the proposed plan. These issues were discussed at the January 7, 1983 Governing Board meeting, and the staff was instructed to prepare a revised Executive Summary of the strategy to clarify the reasons for the preferred course of action. This technical report provides part of the back-up material for that revised Executive Summary.

I. GENERAL DESCRIPTION OF BASIN AND STUDY AREA

The Everglades Agricultural Area (EAA) is an intensely farmed area south of Lake Okeechobee which encompasses approximately 1,045 square miles. Figure 1 details the salient features of the EAA. This area is nearly level and generally treeless, with elevations ranging between 12 and 16 feet NGVD. The soils are organic and are underlain by limestone at depths ranging from two to eight feet. These woild have been drained and water stands on the surface for only a short period of time. Having been drained, the organic soils are subject to oxidation and subsidence. Although initial subsidence is rapid and brief, the soil continues to subside at the rate of approximately one inch per year because of oxidation. To slow the rate of subsidence, high water tables are maintained to the extent possible for all uses. The area has long, warm, relatively humid summers and mild, dry winters. The average annual rainfall is about 59 inches and is seasonally distributed with about 60 percent of the total rainfall coming in the summer rainy season, which extends from June through September. Great variations in rainfall can occur within any particular year, producing flooding in the summer months or drought in the winter and spring months under extreme conditions. The past two years is an excellent example of these extremes as the area experienced severe water shortage conditions between spring 1981 and early spring 1982 followed by heavy rainfall and isolated flooding in late spring and early summer 1982. The EAA was encircled with protective levees L-1, L-2, L-3, L-4, L-5, L-6, L-7, and L-8 in the 1950's as part of the Central and Southern Florida Flood Control Project authorized by Congress in 1948.

That authorization also included the installation of numerous pumping stations, gravity control structures and canal improvements, including the enlargement and diking on both sides of the four old Everglades Drainage District canals constructed in the period 1910-1930 (West Palm Beach, Hillsboro, North New River, and Miami Canals). From Figure 1 it can be seen that runoff generated in the northerly portions of the Miami, North New River, and Hillsboro Canals has been normally discharged through S-2 and S-3 into Lake Okeechobee. Pumping stations S-6, S-7, and S-8 pump runoff to the Water Conservation Areas from the southerly reaches of these three canal basins. In terms of land use, Table 1 displays a breakdown of acreages and percentages by land use category for each basin served by pumping stations S-2, S-3, S-6, S-7, and S-8. It is clear from Table 1 that the S-2 and S-3 basins are intensely developed with agricultural land uses dominating. Significant wetland areas (Holeyland, Rotenberger, and Brown's Farm tracts) are present in the S-7 and S-8 basins. Figure 2 shows the location of the Holeyland and Rotenberger areas and a general breakdown of public and private land ownerships in those areas. There are approximately 15 square miles currently in private ownership, compared with a total area of approximately 95 square miles within the Holeyland and Rotenberger tracts.

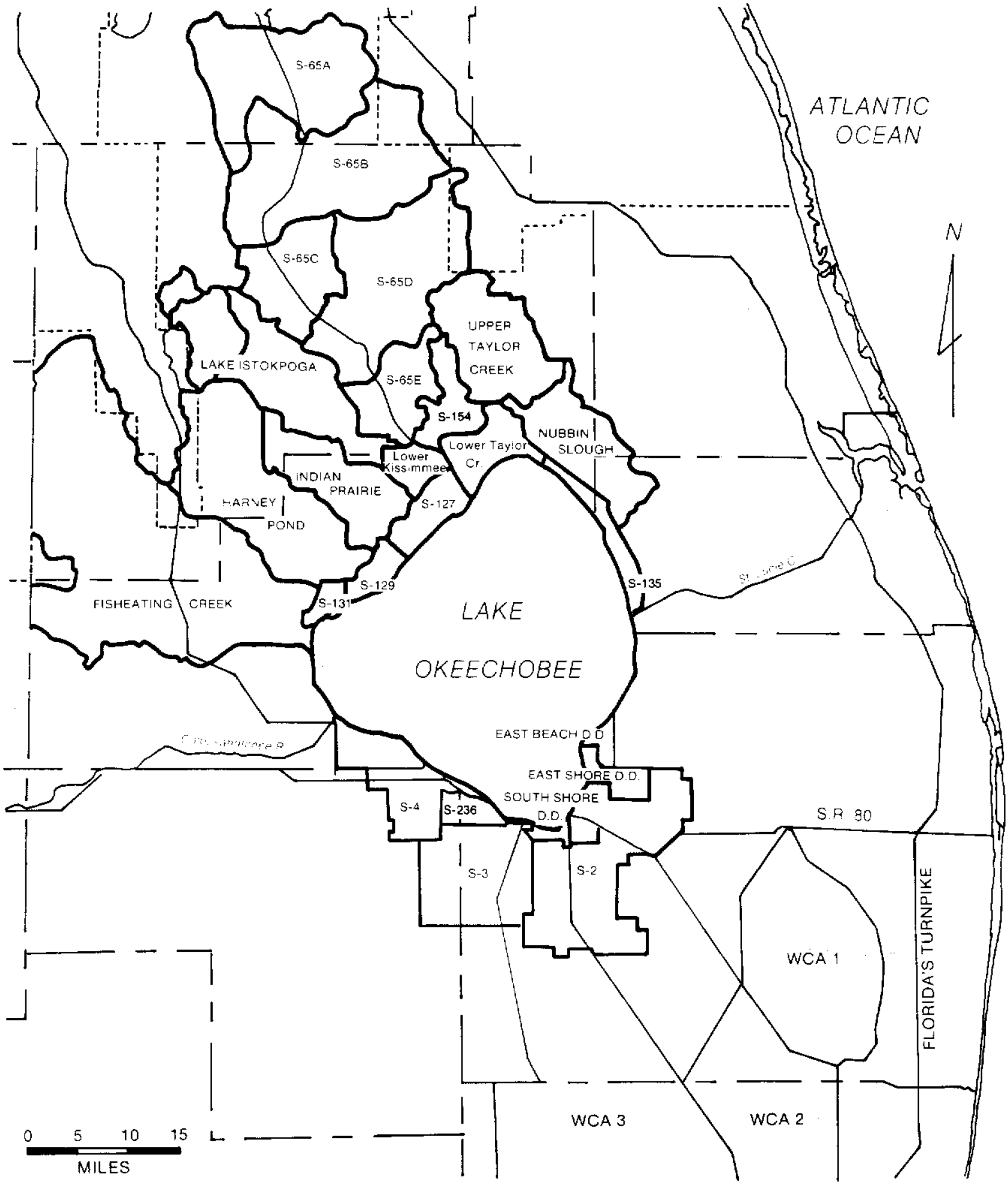


Figure 1 LAKE OKEECHOBEE STUDY AREA

TABLE 1

1979 LAND USE/LAND COVER DATA (ACRES AND PERCENTAGES)

Land Use	S-2 Basin	S-3 Basin	S-6 Basin	S-7 Basin	S-8 Basin	Total
Sugar Cane	96,621 (91.2)	57,380 (88.7)	55,026 (64.8)	52,779 (62.8)	51,982 (40.4)	313,788 (67.0)
Improved Pasture	1,146 (1.1)	3,773 (5.8)	14,062 (16.6)	8,152 (9.7)	14,281 (11.1)	41,414 (8.8)
Truck Crops, Sod	3,936 (3.7)	3,030 (4.7)	10,996 (13.0)	12,812 (15.2)	0	30,774 (6.6)
Low Intensity Urban	2,497 (2.4)	245 (0.4)	449 (0.5)	512 (0.6)	0	3,703 (0.8)
High Intensity Uban	1,180 (1.1)	0	105 (0.1)	141 (0.2)	0	1,426 (0.3)
Uplands	0	0	1,152 (1.4)	0	1,288 (1.0)	2,440 (0.5)
Wetlands	0	0	2,737 (3.2)	9,013 (10.7)	60,726 (47.2)	72,476 (15.5)
Other	593 (0.5)	231 (0.4)	331 (0.4)	617 (0.8)	472 (0.3)	2,244 (0.5)
TOTAL	105,973(100.0)	64,659(100.0)	84,858(100.0)	84,026(100.0)	128,749(100.0)	468,265(100.0)

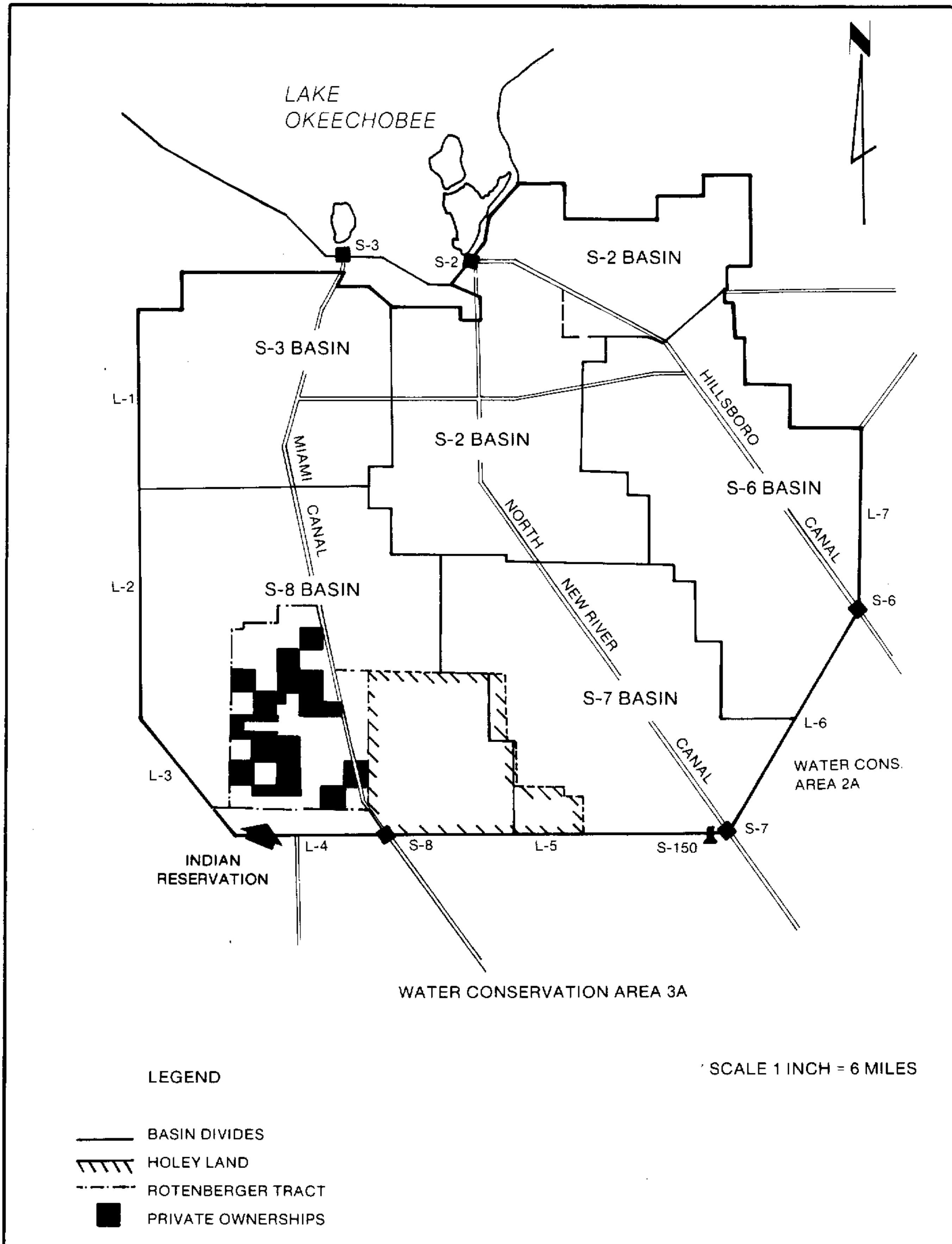


Figure 2 GENERAL STUDY AREA

II. SUMMARY OF PREVIOUS INVESTIGATIONS AND ACTIVITIES

Since 1969, District staff, either singularly or in cooperation with numerous agencies and organizations has been collecting, developing, and analyzing data on water quality, fish, and wildlife in Lake Okeechobee. These numerous studies have prompted several publications and events concerning the lake's water quality problems. Following is a chronology of major water quality studies and events affecting Lake Okeechobee and the EAA.

A. United States Geological Survey (USGS) 1969

The USGS, in cooperation with the District, initiated an intensive water quality data collection effort in Lake Okeechobee.

B. Governor's Conference on Water Management in South Florida, 1971

Lake Okeechobee was recognized as the "hub of water quality and quantity in South Florida."

C. South Florida Water Management District, 1972 - Present

In 1972, the District (then the Central and Southern Florida Flood Control District) began its water quality data collection efforts, which included a comprehensive Lake Okeechobee data collection program.

D. State of Florida (numerous agencies), 1973 - 1976

The Florida Legislature in 1973 created and funded the Special Project to Prevent the Eutrophication of Lake Okeechobee, a multi-agency, three year effort directed toward examining the management of Lake Okeechobee and its tributary basins. Through its own water quality investigations, the District provided data and other information to the Special Project, including the "Report on Investigation of Backpumping Reversal and Alternative Water Retention Sites, Miami Canal, and North New River Canal Basins, Everglades Agricultural Area, December 1975."

E. South Florida Water Management District, 1975

Technical Publication No. 75-1, titled "Chemical and Biological Investigations of Lake Okeechobee, January 1973 - June 1974, Interim Report," was prepared and accepted by the Governing Board. The results of this report, in addition to water quality information for the Kissimmee River Basin, were presented by the District staff at a District sponsored seminar in Fort Pierce, Florida, on March 20, 1975.

F. South Florida Water Management District and the Florida Sugar Cane League, 1975 - 1978

Because of the mounting concern over Lake Okeechobee water quality and the questions regarding stormwater runoff quality from agricultural lands, the District and the League cooperatively initiated intensive water quality studies in the EAA to supplement the on-going District studies in Lake Okeechobee.

G. South Florida Water Management District, 1978

Technical Publication No. 78-3, titled "Water Quality in the Everglades Agricultural Area and Its Impact on Lake Okeechobee," was prepared and accepted by the Governing Board in the summer of 1978.

H. South Florida Water Management District, 1980

Interim actions for reducing nutrient contributions from the EAA to Lake Okechobee were approved by the Governing Board on January 11, 1980.

I. South Florida Water Management District, 1981

Technical Publication No. 81-2, titled "Lake Okeechobee Water Quality Studies and Eutrophication Assessment," was accepted by the Governing Board in May 1981. This report served as the foundation for developing management actions to reduce nutrient loading from the EAA and other tributaries to the lake.

J. South Florida Water Management District, 1981

The "Executive Summary, Water Quality Management Strategy for Lake Okeechobee" was accepted by the Governing Board in December 1981. The technical back-up report was also issued in December 1981.

K. South Florida Water Management District, 1982

At its June 1981 regular meeting, the Governing Board approved a modified Interim Action Plan (pumping schedule) for the EAA to remain in effect until a more permanent solution is in place.

L. South Florida Water Management District, 1982

At its November 1982 regular meeting, the Governing Board approved the Executive Summary addendum which included a proposed Master Plan for the EAA.

III. ANALYSIS OF EXISTING SOURCES

Based on data evaluated and presented in District Technical Publication No. 81-2 and in reports prepared under the Lake Okeechobee TOP process (see Table 2), pump stations S-2 and S-3 were indicated as the most important contributors of nitrogen and phosphorous to Lake Okeechobee from the EAA. Thus, management alternatives in the EAA are being focused on the S-2 and S-3 basins.

Using land use loading rates from previous and on-going studies (see Table 3) and land use/land cover data compiled by the District's Land Resources Division, average annual loadings for the S-2 and S-3 watersheds were calculated. Further treatment plant operation records were researched to identify point source discharges in each area, such as municipal wastewater treatment plants. Tables 4 and 5 present the results of those calculations. Sugar cane is the primary land use; and in conjunction with soil type, contributes the major portions of total phosphorous and total nitrogen loads. Also, point source discharges in the S-2 basin are significant sources of total phosphorous in that basin.

TABLE 2

PERCENTAGE SUMMARY OF WATER, PHOSPHOROUS AND NITROGEN INPUTS TO LAKE OKEECHOBEE

Inflow	Water	Total Phosphorous	Total Nitrogen
Rainfall	38.8%	16.7%	24.3%
Kissimmee River	30.9%	20.3%	24.6%
S-2 and S-3	7.2%	6.4%	23.3%
Fisheating Creek	5.8%	9.8%	7.0%
S-71	4.9%	9.0%	6.3%
Taylor Creek/Nubbin Slough (S-191)	4.4%	28.5%	5.8%
S-84	4.0%	1.9%	3.1%
S-72	1.1%	1.7%	1.6%
S-4	1.0%	2.2%	1.7%
S-133 and S-135	1.0%	1.7%	1.1%
S-127, S-129 and S-131	0.8%	1.6%	0.8%
Other Inflows	0.1%	0.2%	0.4%

TABLE 3

LOADING COEFFICIENTS FOR VARIOUS LAND USE TYPES

Land Use	Total P lb/ac/yr	Total N lb/ac/yr
Low intensity urban[1]	1.6	5.9
High intensity urban[1]	2.4	12.0
Truck crops, sod farms[2]	1.9	33.2
Sugarcane[2]	0.6	24.2
Citrus[1]	0.2	4.0
Dairy Farms[3]		
Intensely managed areas	15.3	38.7
Upland pasture	4.2	9.0
Cattle feedlots[3]	15.3	38.7
Improved pasture (beef cattle)		
Northern basins[4]	1.2	4.5
S-2 and S-3 basins[2]	0.5	9.2
S-4 basin[4]	1.2	4.5
Uplands[4]	0.05	1.1
Wetlands[1]	0.18	4.9
Wastewater treatment plant[5]	7.0 mg/l	20.0 mg/l
Lake Okeechobee load allocation[6]	0.34	2.9

[1]Wanielista

[2]CH_2M-Hill

[3]SFWMD Uplands Demonstration Projects

[4]Average of SFWMD and Wanielista's data

[5]Plant operation reports

[6]Calculated from Technical Alternatives Report

TABLE 4

NUTRIENT LOADINGS FROM S-2 AND S-3 WATERSHEDS

Land Use	Acres	Total P Load, lb/yr	Total N Load, lb/yr
Low Intensity Urban	2,716	4,346	16,025
High Intensity Urban	1,194	2,866	14,328
Crops, Sod	6,966	13,235	231,271
Sugarcane	154,001	92,401	3,726,824
Citrus	19	4	76
Dairy, Feedlots	0	0	0
Improved Pasture	4,919	2,460	45,255
Uplands	0	0	0
Wetlands	0	0	0
SUB-TOTALS	169,815	115,312	4,033,779
	Flow, MGD	Total P Load, lb/yr	Total N Load, lb/yr
Wastewater Treatment Plants	2.0	42,617	121,764
TOTAL		157,929 (79 Tons)	4,155,543 (2,078 Tons)

TABLE 5

COMPARISON OF CALCULATED VS. MEASURED BASIN LOADS

Basin	Flow AF/mi^2-yr	Total P, Tons/Yr		Total N, Tons/Yr	
		Calculated	Measured	Calculated	Measured
S-2	1,180	58	35	1,315	1,548
S-3[1]	552(1,104)	21(11)	7	763(382)	373
TOTALS		79(69)	42	2,078(1,697)	1,921

[1]The data indicate that approximately 1/2 of the flow (and consequently 1/2 of the total P and total N loading) is directed toward one or more outlets other than S-3. Adjusting for this circumstance results in the loadings in parentheses, which show fairly good agreement with the empirical data.

IV. ANALYSIS OF CONTROL ALTERNATIVES

A. Summary of December 1981 Report

As presented in the report Lake Okeechobee Water Quality Management Plan, Alternative Evaluation, December 1981, a wide range of alternatives for reducing nutrient loading to Lake Okechobee from the S-2 and S-3 basins were evaluated. These included regional and sub-regional storage, on-site storage and other BMPs, conventional and advanced (reverse osmosis) treatment plants, and diversion to the Water Conservation Areas (Interim Action Plan or IAP). Based on an analysis of costs, nutrient removal effectiveness, and impacts on water resources and other factors, a ranking of options in the EAA was developed in order to determine the preferred alternative for implementation in the EAA. The results of the analysis and ranking indicated that regional storage of runoff on the Holeyland tract, with water releases during the dry season, was the preferred alternative. There are several reasons for proposing the implementation of this option, as pointed out in the December 1981 report:

1. Regional storage of runoff on the Holeyland tract provides for an additional water storage area for meeting a portion of the water supply demands on Lake Okeechobee and WCA 3A.

2. Regional storage and water recycling is the least cost alternative which also meets the guidelines established during the study.

3. Compared with the IAP, there is more water available for water supply from Lake Okeechobee on an annual average basis.

4. Regional storage has a greater probability of achieving nitrogen load reductions to Lake Okeechobee than on-site storage due to the treatment capability of one large storage area versus numerous smaller storage areas.

5. Regional storage has the potential to provide more benefits to WCA 3A than the other options. These potential benefits include:

   a. A portion of the excess runoff generated in the S-7 and S-8 basins would be treated prior to being discharged to WCA 3A.

   b. Some degree of sheetflow over the north end of WCA 3A can be reestablished by discharging excess water from the Holeyland at several locations along the northern levee of WCA 3A.

Tables 6 and 7 show, respectively, the final ranking of alternatives for the EAA and a summary of preferred alternatives.

TABLE 6

FINAL RANKING

WATERSHED: EVERGLADES AGRICULTURAL AREA (S-2 AND S-3)

Rank	Alternative	Total Points
1	Regional storage on Holeyland Tract	23
2	Interim Action Plan	25
3	Regional storage on Holeyland Tract and Trustees Tract	32
4	Subregional storage (Rotenberger, Holeyland, Trustees Tract, and Brown's Farm)	74
5	Conventional treatment plants at S-2 and S-3	122
6	On-site storage	127
7	Reverse Osmosis treatment plants	132

TABLE 7

SUMMARY OF PREFERRED ALTERNATIVES

Watershed	Alternative	Capital Cost, $ Million	Total P Reduction, Tons		Total N Reduction, Tons	
			After Controls	Required	After Controls	Required
Taylor Creek/ Nubbin Slough (S-191)	On-site management	13.2	169.8	168	302.7	302
S-2 and S-3	Holeyland	14.5	38.2	17	1,724.6	1,670
Harney Pond Canal (S-71)	On-site management	9.1	28.8	28	189.4	154
Fisheating Creek	On-site management	12.9	30.8	14	213.4	141
S-4	Diversion to C-43	1.4	13.4	8	127.4	80
C-38[1]	On-site management	30.9	40.7	33	493.2	354
TOTAL OVERALL DESIRED REDUCTIONS		82.0	321.7	268	3,050.7	2,705

[1]This is only one of many alternatives currently being considered by the U.S.A.C.E. in the re-study of the Kissimmee River and has not been selected as the least cost alternative. The figures are presented for comparative purposes only.

B. Description of Alternative Holeyland Configurations

As indicated earlier, the District was requested to develop a Master Plan for state-owned lands in the southern EAA; namely, the Holeyland and Rotenberger tracts. There are two basic alternative Holeyland configurations which were evaluated. These are depicted in Figures 3 and 4 and are more fully described as follows:

1. Holeyland 1

   This configuration is the same as the described in the December 1981 report. An alternative alignment for the eastern intake canal is indicated as a sub-alternative.

2. Holeyland 2

   Under this option, the configuration is the same as for Holeyland 1 except the "toe" area is also included.

A breakdown of the required facilities and costs (capital costs and annual operation and maintenance costs) for each alternative is provided in Tables 8 and 9.

C. Description of Alternative Rotenberger Configurations

Six basic alternative configurations for the Rotenberger area were examined (see Figures 5-10), as follows:

1. Rotenberger 1

   This alternative has the same configuration as described in the December 1981 technical report on Lake Okeechobee.

2. Rotenberger 2

   For this option, the configuration is the same as for Rotenberger 1 except easements would be acquired through the Indian lands in order to provide for flow-through distribution to Water Conservation Area 3A west of C-123.

3. Rotenberger 3

   The configuration for this alternative is the same as for Rotenberger 1, except the area north to the Manley Ditch is included.

4. Rotenberger 4

   This option is a combination of the configurations for Rotenberger 2 and Rotenberger 3.

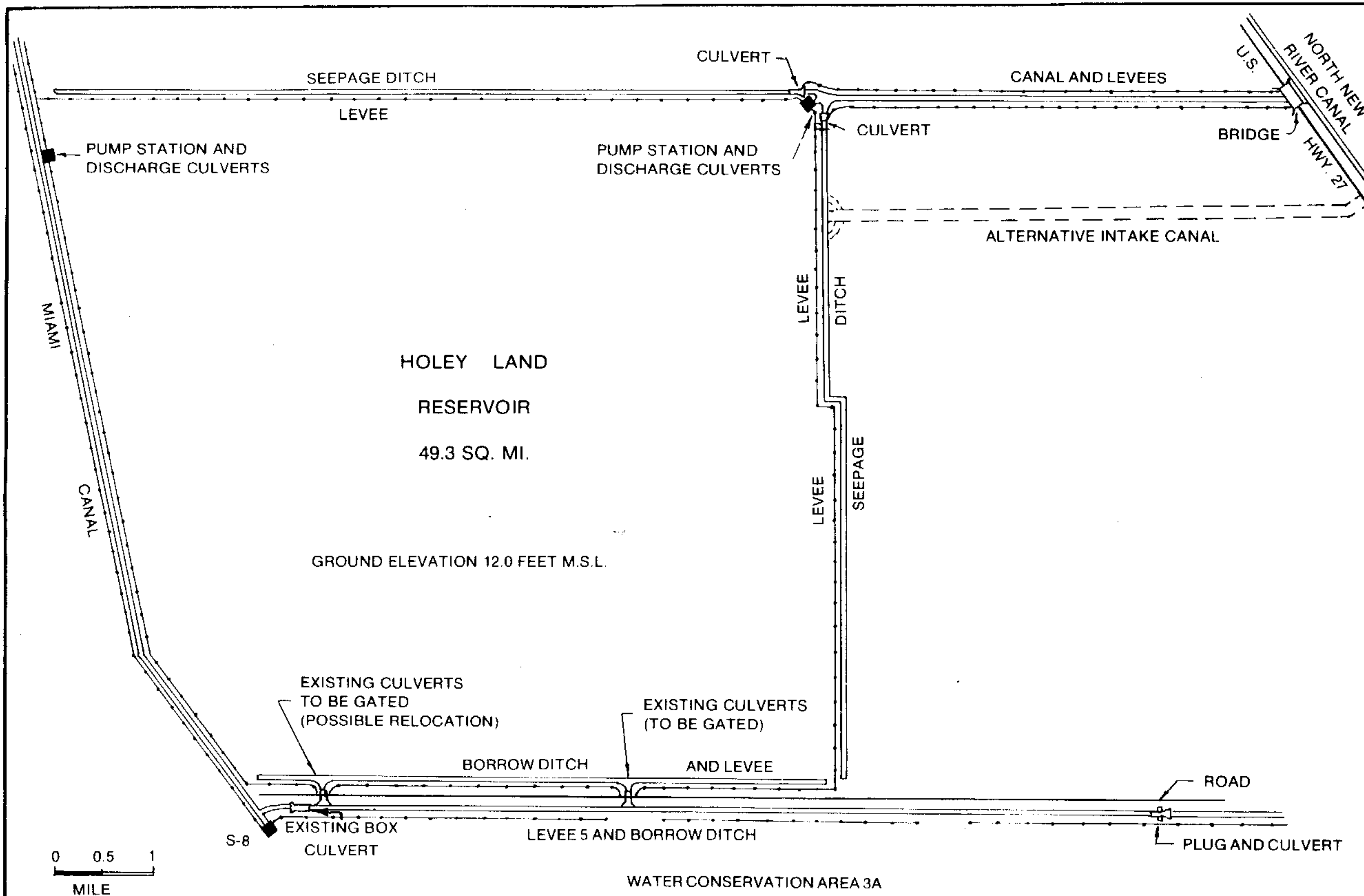


Figure 3 HOLEYLAND 1

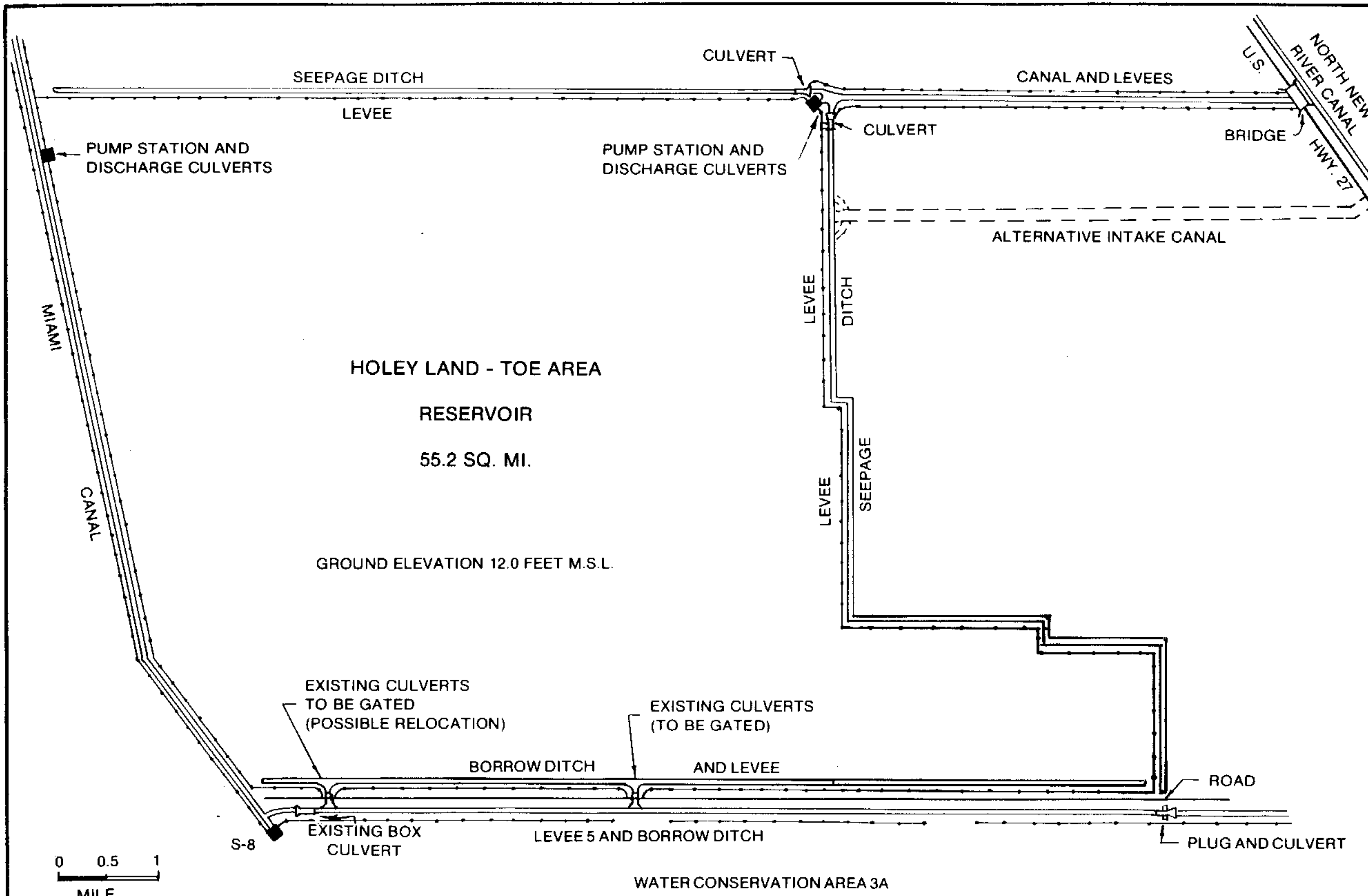


Figure 4 HOLEYLAND 2

TABLE 8

HOLEYLAND 1 COSTS

Capital Costs

2 - 42" culverts in seepage ditch............$	16,800
Gating existing L-5 culverts.................	252,000
1 - 84" culvert in L-5 borrow canal..........	42,000
Gapping L-5 levee and tie-back...............	33,600
Intake canal levee...........................	161,300
Bridge at U.S. Highway 27....................	252,000
2 - 72" culverts at each pump station........	302,400
1 - 550 cfs pumping station..................	3,124,800
1 - 750 cfs pumping station..................	3,662,400
Perimeter levees.............................	2,955,000
2 Intake canals..............................	1,001,000
Land cost and canal R/W......................	1,600,000
Collector ditch..............................	1,730,000
Sub-Total.........	$15,133,300
Divide structure in NNRC.....................	1,210,000
TOTAL.........	$16,343,300

Annual Operation and Maintenance Costs

Levee & Structure O & M	Pump Station O & M	Total
$11,100	$145,000	$156,100

TABLE 9

HOLEYLAND 2 COSTS

Capital Costs

2 - 42" culverts in seepage ditch............$	16,800
Gating existing L-5 culverts.................	252,000
1 - 84" culvert in L-5 borrow canal..........	42,000
Gapping L-5 levee and tie-back...............	33,600
Intake canal levee...........................	161,300
Bridge at U.S. Highway 27....................	252,000
2 - 72" culverts at each pump station........	302,400
1 - 550 cfs pumping station..................	3,124,800
1 - 750 cfs pumping station..................	3,662,400
Perimeter levees.............................	3,501,000
2 Intake canals..............................	1,001,000
Land cost and canal R/W......................	1,600,000
Collector ditch..............................	1,730,000
Sub-Total.........	$15,679,300
Divide structure in NNRC.....................	1,210,000
TOTAL.........	$16,889,300

Annual Operation and Maintenance Costs

Levee & Structure O & M	Pump Station O & M	Total
$13,800	$144,500	$158,300

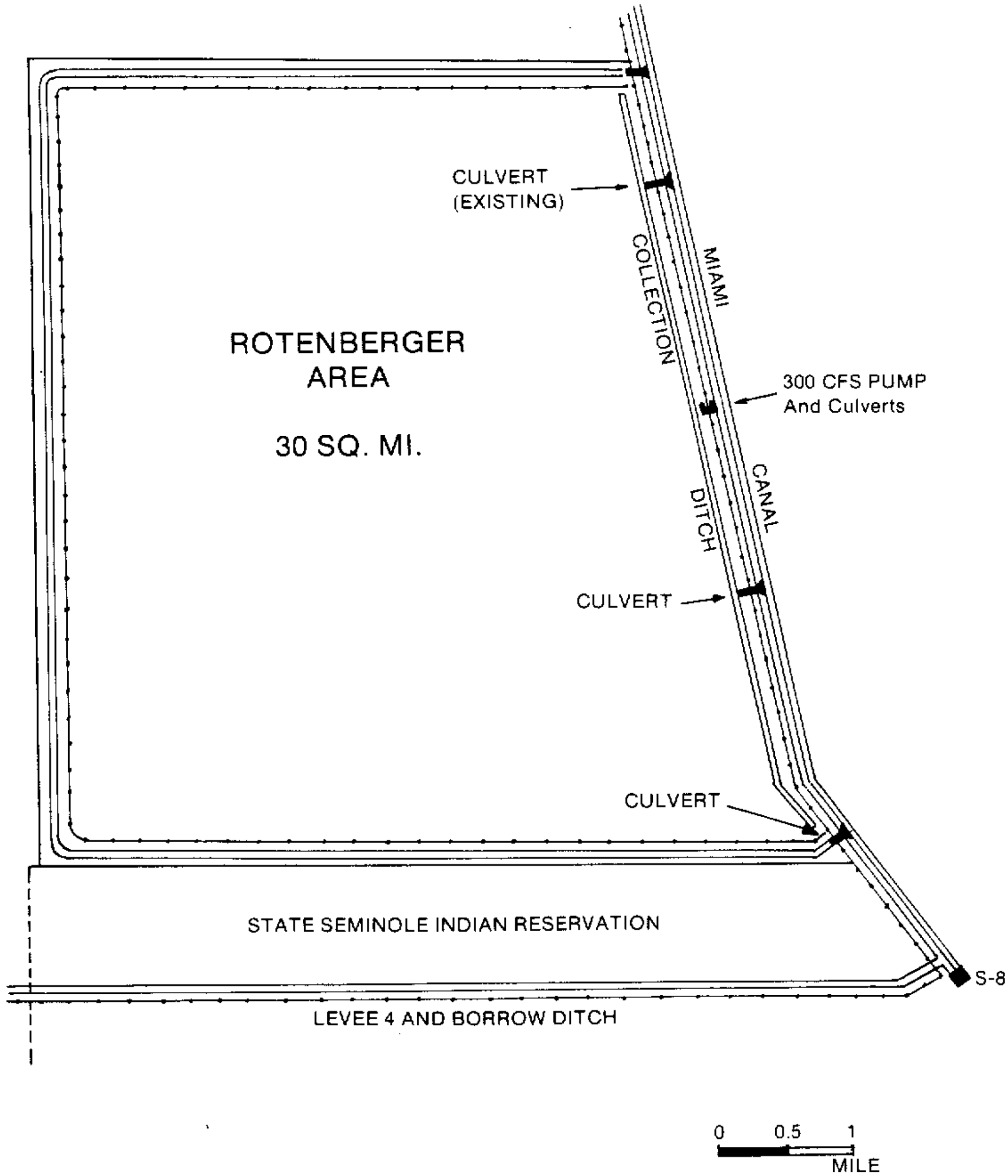


Figure 5 ROTENBERGER 1

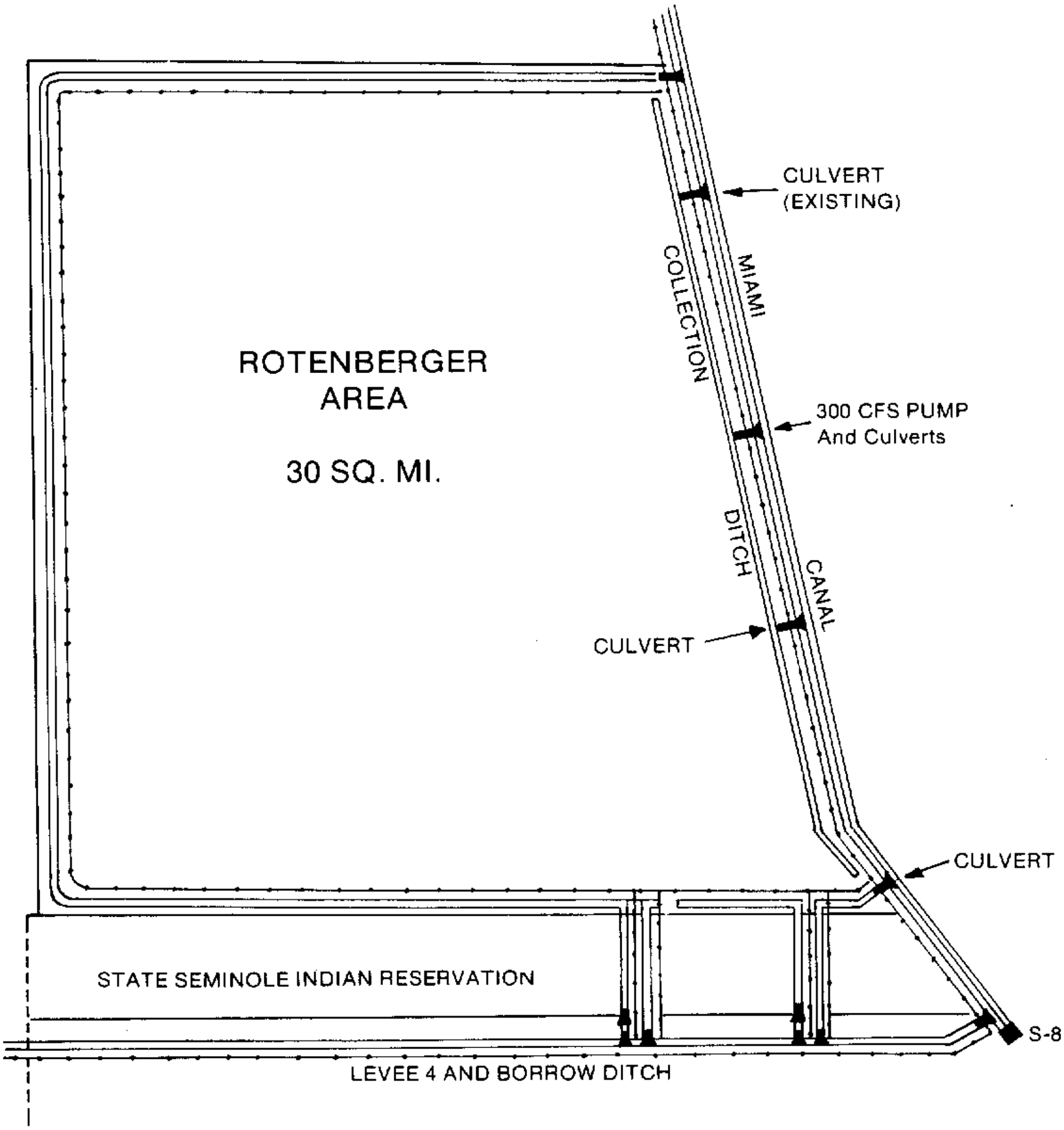


Figure 6 ROTENBERGER 2

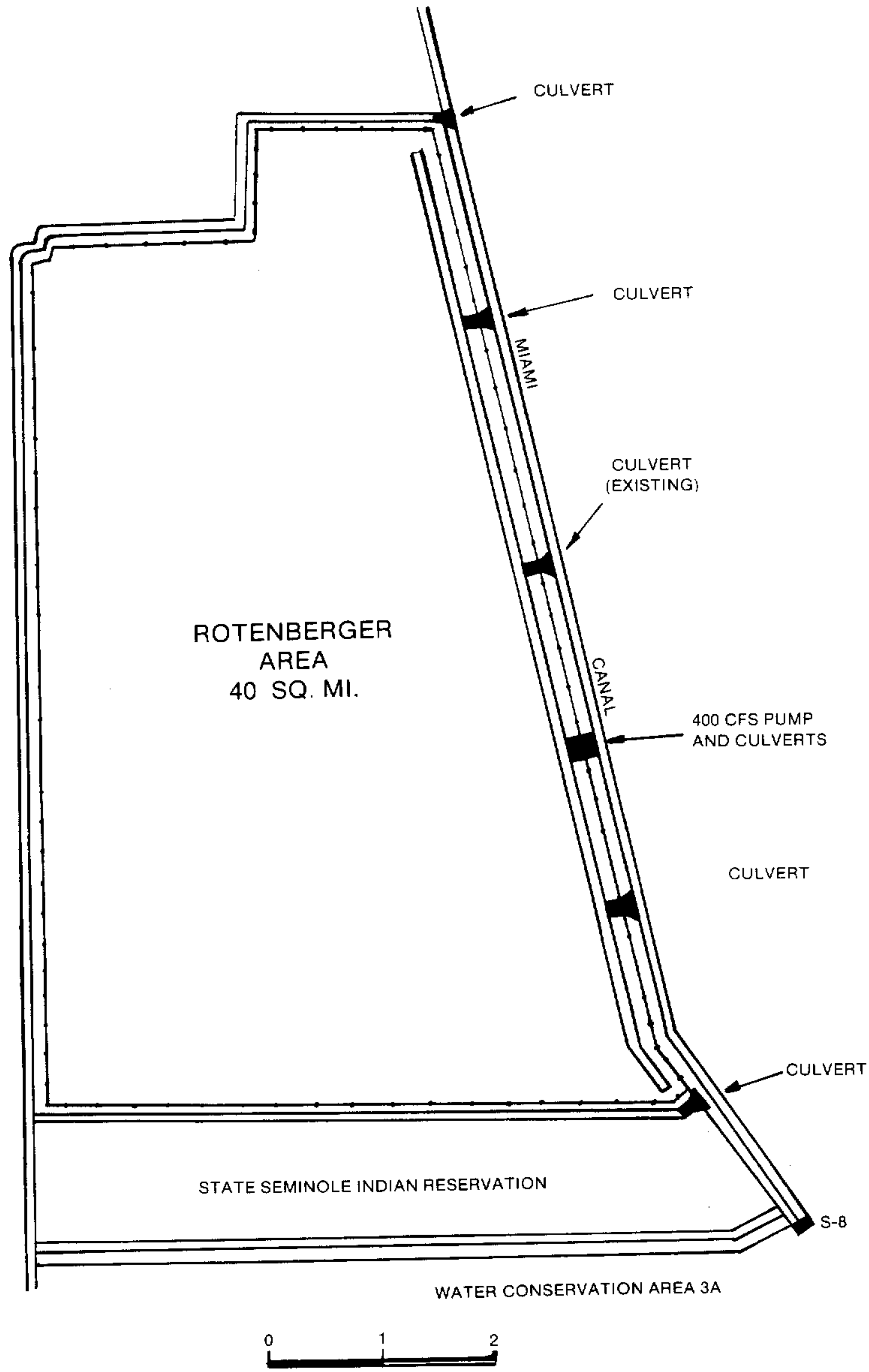


Figure 7 ROTENBERGER 3

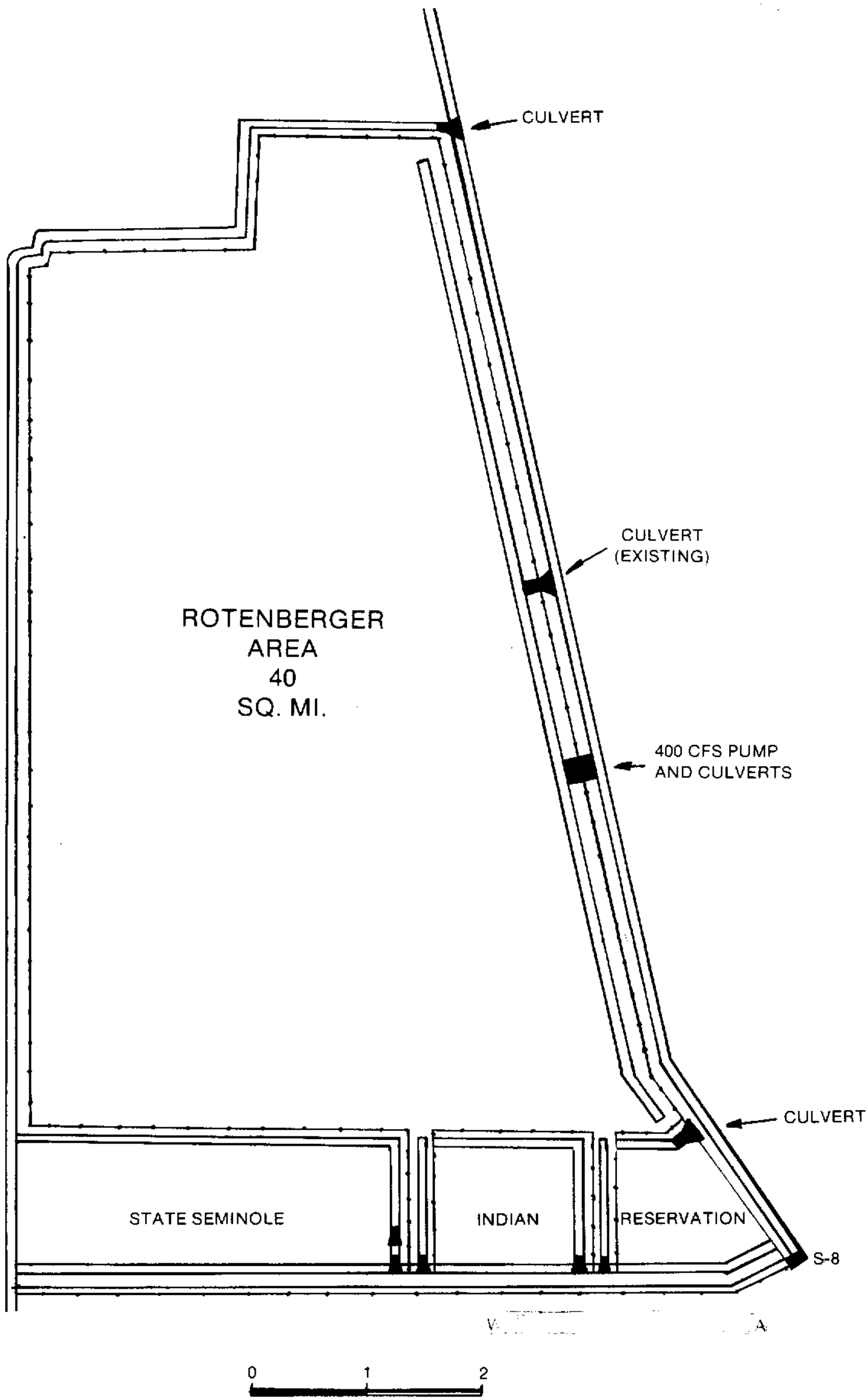


Figure 8 ROTENBERGER 4

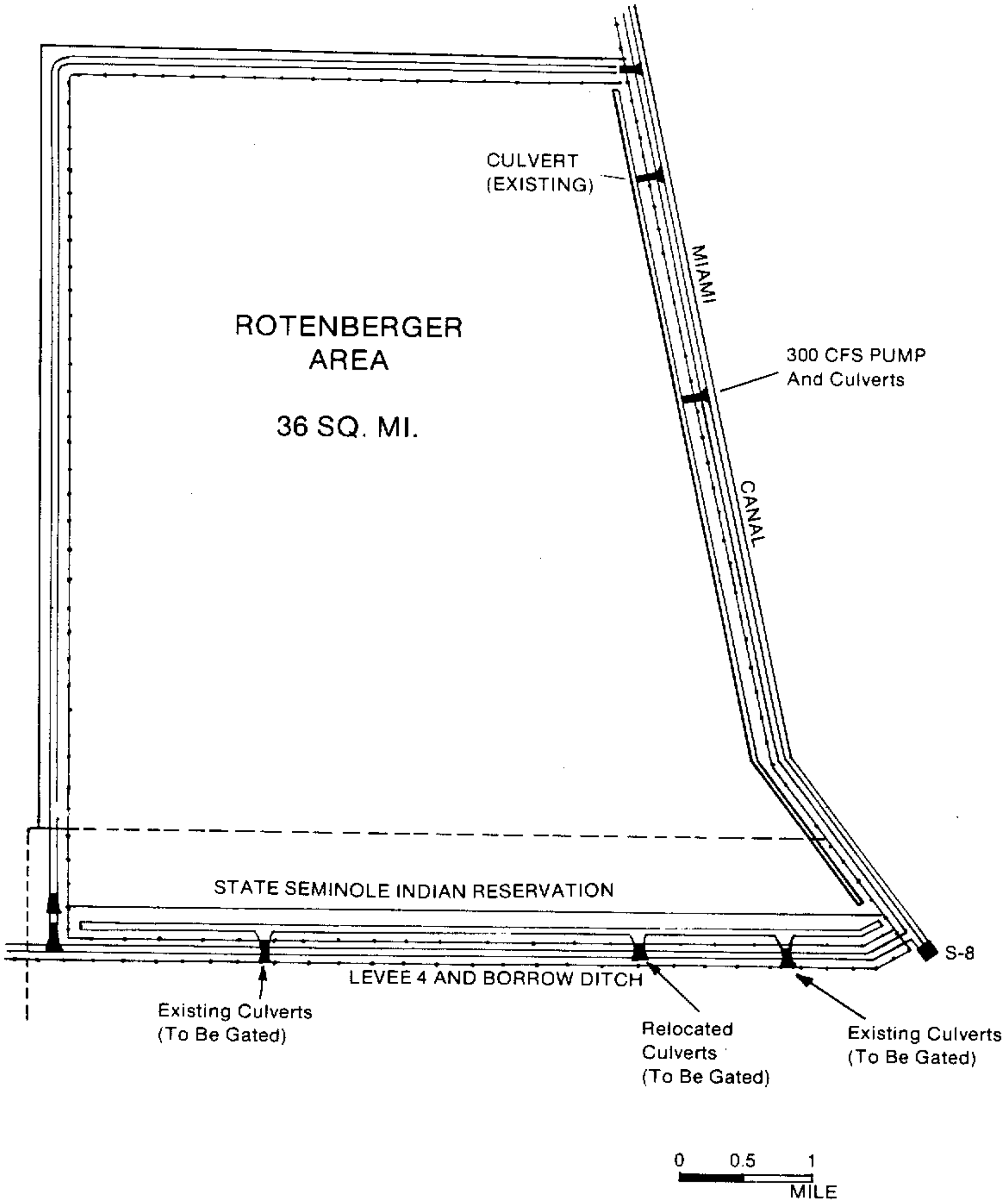


Figure 9 ROTENBERGER 5

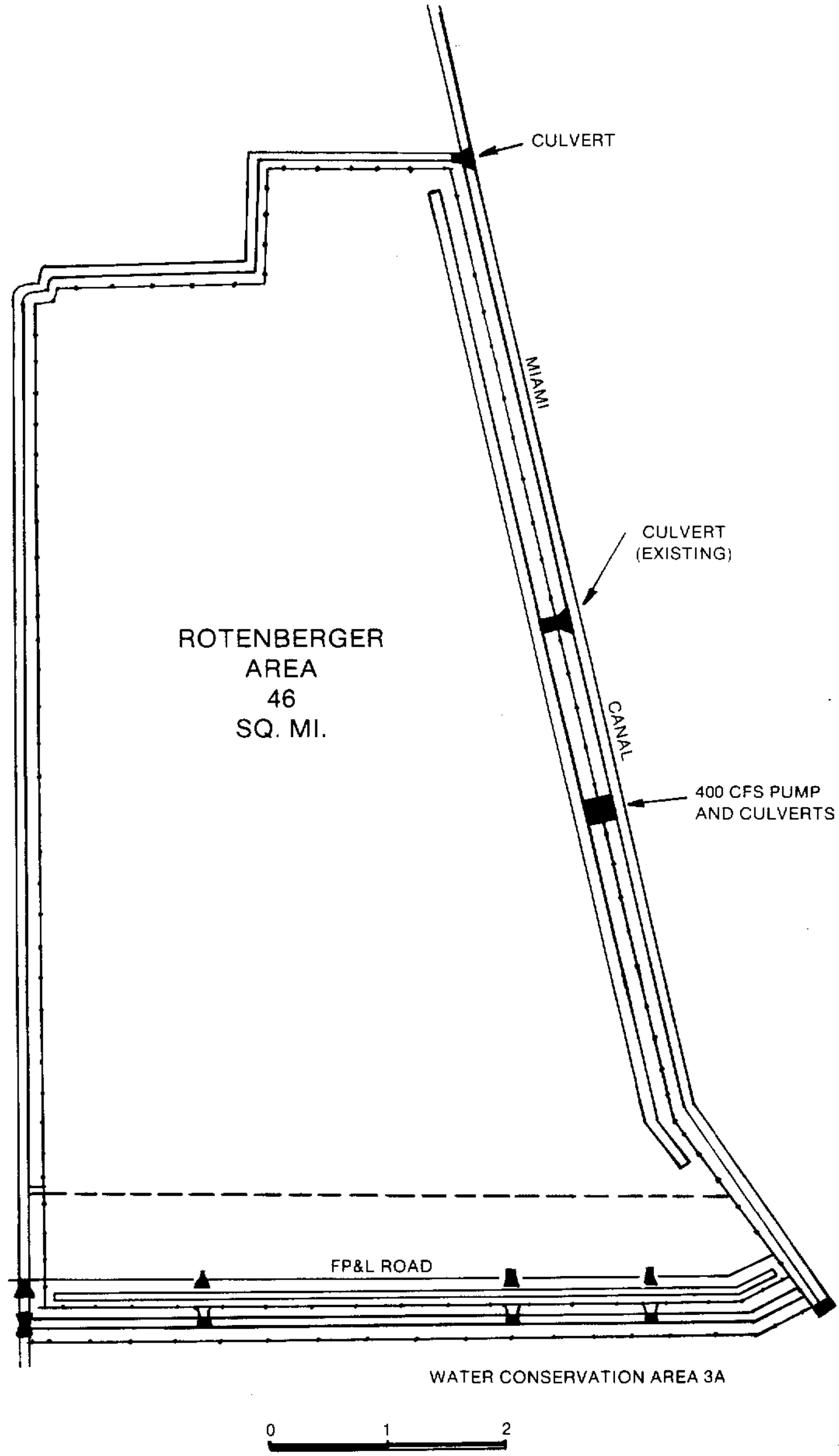


Figure 10 ROTENBERGER 6

5. Rotenberger 5

The Indian lands at the bottom of the Rotenberger tract are added to the configuration for Rotenberger 1 under this option. Flow-through distribution to WCA 3A west of C-123 would be provided.

6. Rotenberger 6

This configuration is a combination of the configurations for Rotenberger 3 and Rotenberger 5 and represents the configuration preferred by the Florida Game and Fresh Water Fish Commission.

As opposed to the Holeyland alternatives, no fish concentration canals were included for the Rotenberger configurations since the proposed water depth evaluated was 0'-1.0'. Required facilities and costs (capital and annual operation and maintenance costs) for each alternative Rotenberger area configuration are listed in Tables 10-15.

D. Screening of Alternatives

A summary of first costs (construction and land acquisition) and annual operation and maintenance costs for the two alternative Holeyland configurations and six alternative Rotenberger configurations is provided in Table 16. It must be recognized that the construction costs are based on COE design considerations (design life of 50 years). Based on cost considerations, the Holeyland 1 configuration (toe area excluded) was selected. For the Rotenberger area, the two least cost options, in terms of construction costs, are Rotenberger 1 (without Indian lands) and Rotenberger 5 (Indian lands included), with an estimated cost differential of $508,600. Although Rotenberger 5 is slightly more expensive (construction costs), there are certain environmental benefits it has which Rotenberger 1 does not have. Specifically, Rotenberger 5 provides for a partial restoration of sheetflow to WCA 3A west of the Miami Canal. In terms of land acquisition, if the Indian lands could be obtained in a land swap, the total first cost of Rotenberger 5 would be reduced to $9,617,400. Based on these considerations, Rotenberger 5 is the preferred alternative. If negotiations for a land swap involving the Indian lands are not successful, then Rotenberger 1 would become the preferred alternative.

E. Preferred Holeyland and Project Configuration

Perimeter levees (see Figure 11) will be required only on the north, east, and south sides; the existing levee of the Miami Canal on the west side being adequate in grade and cross-section for the considered regulation schedules. The south perimeter levee is to be located north of the existing FP&L transmission line, at a distance approximately 450 feet north of the L-5 interior levee, which also serves as the access road to both S-8 and the transmission line towers. The required levee has a 10 foot crown width, with side slope of IV on 2H, and a top elevation of 19.0 feet msl. "Coring" of the levee by removal of muck under the middle 10 feet of the levee base would be required. The total length of the levee construction is 20.5 miles. The system requires two pumping stations of 750 cfs and 550 cfs and an intake canal from the North New River Canal to

TABLE 10

ROTENBERGER 1 COSTS

Capital Costs

1 - 300 cfs pumping station..................	$ 1,747,000
Discharge culverts..........................	243.600
Collector ditches............................	562,800
Perimeter levee..............................	475,400
Land cost....................................	6,080,000
TOTAL.........	$ 9,108,800

Annual Operation and Maintenance Costs

Levee & Structure O & M	Pumping Station O & M	Subtotal
$6,550	$87,400	$93,950

TABLE 11

ROTENBERGER 2 COSTS

Capital Costs

1 - 300 cfs pumping station..................	$ 1,747,000
Discharge culverts..........................	336,000
Collector ditches...........................	844,200
Perimeter levee.............................	689,300
Land cost...................................	6,322,400
Relocation of project culvert...............	20,000
Gating existing L-4 culverts................	252,000
Gapping L-4 levee and tie-back..............	33,600
1 - 84" gated culvert in L-4................	42,000
TOTAL.........	$10,286,500

Annual Operation and Maintenance Costs

Levee & Structure O & M	Pumping Station O & M	Subtotal
$8,310	$87,400	$95,710

TABLE 12

ROTENBERGER 3 COSTS

Capital Costs

1 - 400 cfs pumping station	$ 3,528,000
Discharge culverts	319,200
Collector ditches	844,200
Perimeter levee	618,000
Land cost	8,000,000
TOTAL	$13,309,400

Annual Operation and Maintenance Costs

Levee & Structure O & M	Pumping Station O & M	Subtotal
$8,220	$116,500	$124,720

TABLE 13

ROTENBERGER 4 COSTS

Capital Costs

1 - 400 cfs pumping station	$ 3,528,000
Discharge culverts	319,200
Collector ditches	844,200
Perimeter levee	831,900
Relocation of project culvert	20,000
Gating existing L-4 culverts	252,000
Gapping L-4 levee and tie-back	33,600
Land cost	8,242,400
1 - 84" gated culvert in L-4	42,000
TOTAL	$14,113,300

Annual Operation and Maintenance Costs

Levee & Structure O & M	Pumping Station O & M	Subtotal
$10,100	$116,500	$126,600

TABLE 14

ROTENBERGER 5 COSTS

Capital Costs

1 - 300 cfs pumping station.................	$ 9,617,400
Discharge culverts..........................	226,800
Collector ditches...........................	844,200
Northern levee..............................	221,900
Relocation of project culvert...............	30,000
Gating existing L-4 culverts & tie-back......	252,000
1 - 84" culvert (L-4 borrow)................	42,000
Raise existing FP&L Road....................	133,500
Install 4 - 66" culverts under FP&L..........	40,000
Land cost...................................	12,800,000
TOTAL............	$16,337,400

Annual Operation and Maintenance Costs

Levee & Structure O & M	Pumping Station O & M	Subtotal
$9,550	$87,400	$96,900

TABLE 15

ROTENBERGER 6 COSTS

Capital Costs

1 - 400 cfs pumping station..................	$ 3,528,000
Discharge culverts...........................	319,200
Collector ditches............................	844,200
Perimeter levee..............................	332,800
Relocation of project culvert................	20,000
Gating existing L-4 culverts.................	252,000
Gapping L-4 levee and tie-back...............	33,600
1 - 84" gated culvert in L-4 borrow..........	42,000
Raising existing FP&L Road...................	133,500
Land cost....................................	14,720,000
TOTAL.........	$20,225,300

Annual Operation and Maintenance Costs

Levee & Structure O & M	Pumping Station O & M	Subtotal
$9,550	$116,500	$126,000

TABLE 16

SUMMARY OF ALTERNATIVE COSTS

Alternative	Land	Construction	Total First Cost	Annual O & M
Holeyland 1	$ 1,600,000	$14,743,300	$16,343,300	$156,000
Holeyland 2	1,600,000	15,289,300	16,889,300	158,300
Rotenberger 1	6,080,000	3,028,800	9,108,800	93,950
Rotenberger 2	6,322,400	3,964,100	10,286,500	95,710
Rotenberger 3	8,000,000	5,309,400	13,309,400	124,720
Rotenberger 4	8,242,400	5,870,900	14,113,300	126,600
Rotenberger 5	12,800,000	3,537,400	16,337,400	96,900
Rotenberger 6	14,720,000	5,505,300	20,225,300	126,000

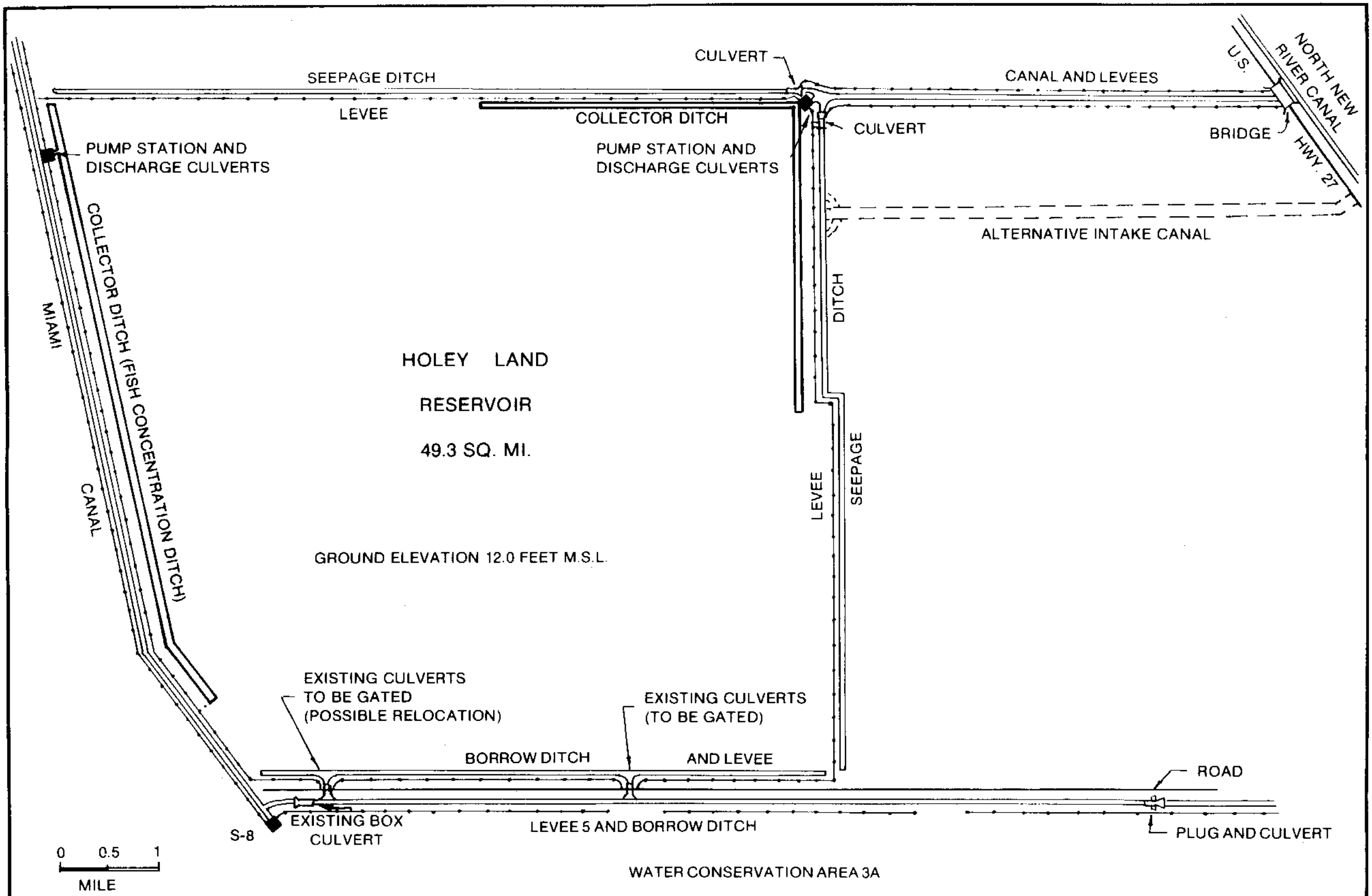


Figure 11 HOLEYLAND RESERVOIR

the proposed reservoir. The 750 cfs pumping station will be located at the northeast corner of the proposed reservoir, as shown in Figure 11. The intake channel will be designed to handle 750 cfs of runoff from the North New River Canal basin. The levee on both sides of the intake canal will be tied into the North New River Canal levee on the east and to the detention area levees on the west. Design grade for the intake canal levee will be at 17.5 feet msl. Embankment material for the levee construction will be taken from adjacent continuous borrow canals. On the north and east sides, the borrow canals will serve as seepage collectors. At the northeast corner of the retention area, gated 42 inch culverts connecting the north and east borrow canals with the pumping station intake canal will be provided. The south perimeter levee borrow canal will be placed in the detention area. No additional outlet capacity southward to Water Conservation Area 3A would be required since the existing outlets would be adequate. These outlets consist of a six barrel, 72 inch culvert installation 0.5 mile east of S-8. The flashboard risers on all culverts would be replaced by gates. A 550 cfs pumping station will be located about one-half mile from the northwestern corner of the proposed resrevoir with two 72 inch discharge culverts. This pumping station will pump runoff from the Miami Canal basin to the proposed reservoir. Twelve miles of collector ditch will be constructed along the east, west, and north sides of the proposed reservoir to serve as fish concentration canals and also provide better flow capability for the delivery of irrigation water from the proposed reservoir.

It must be recognized that this is a preliminay design of the project. As detailed planning and design proceeds, more definitive alignments, locations, dimensions, and costs of facilities will be developed. For example, detailed alignments and designs of the collector/fish concentration canals will be prepared based on water delivery capabilities, fisheries benefits, and other considerations.

Also, a substantial cost savings could result if the alternate eastern intake canal alignment (Gulf and Western Main Canal) can be obtained. This alignment is located approximately one mile south of the previously described alignment. The existing canal in this alignment has an estimated design capacity of 550 cfs and therefore, would have to be enlarged to handle 750 cfs. At the discharge point to the North New River Canal, there are four existing 49,000 gpm discharge pumps (550 cfs) and one 49,000 gpm 2-way pump which discharge through a double barrel box culvert. A bridge over the discharge canal at U.S. Highway 27 also exists. Acquisition and relocation of these pumps could result in a cost savings.

F. Preferred Rotenberger Project Configuration

The general facilities layout is shown in Figure 12. Levee design criteria are the same as for the Holeyland sites except that the "coring" is not necessary due to the small heads across the levees. Levees will be required on the north and will be included as part of the proposed flood relief plan for Hendry County, since planning for this program is proceeding concurrently. That is, a proposed channel will be tied into the Miami Canal on the east and to Levee L-3 near the Deer Fence Canal on the west. The alignment of this proposed channel will be along the

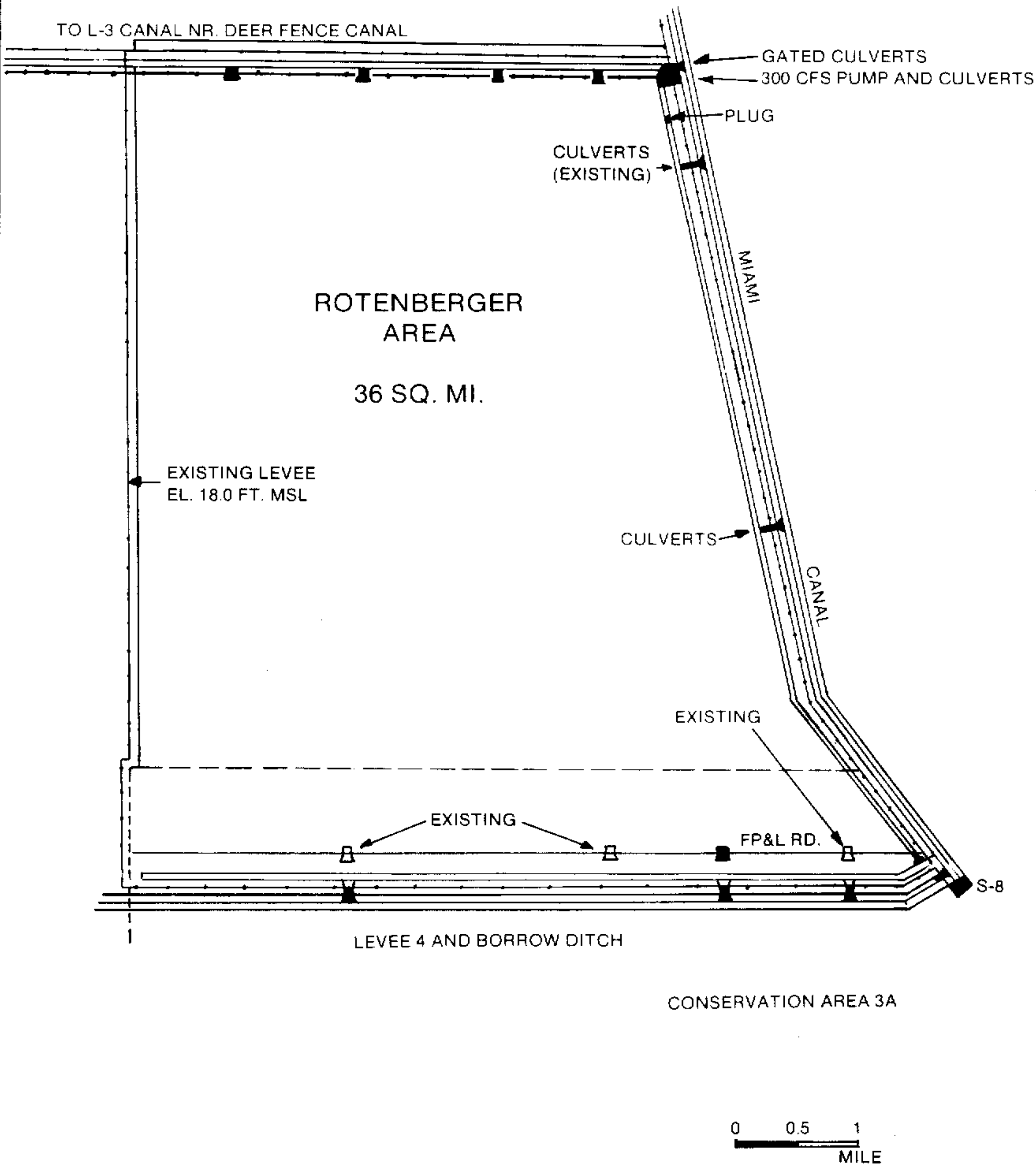


Figure 12 ROTENBERGER AREA

northern boundary of the proposed Rotenberger project. The existing Miami Canal levee on the east side and the existing levee L-4 on the south side, as well as the existing levee on the west side (U.S. Sugar Co., Hendry County) are adequate with a crown width of 10 feet at a minimum grade of 18.0 feet msl on the west side. Two collection ditches inside the Rotenberger area should be constructed to provide better capability for sheetflow through the marsh area. A 300 cfs pump located in the Miami Canal west levee, near the northeast corner of the proposed area, will deliver redirected water into the reservoir, as required. Two 72-inch culverts with gates have to be installed, one through the existing Miami Canal west levee and the other to be installed approximately 3.5 miles north of S-8. There are 12 existing 66-inch culverts with flashboard controls located at three locations along the existing L-4 levee. The flashboard risers on all the culverts would be replaced by gates. Three of the 12 culverts would be relocated to a site approximately two miles west of S-8 from its original location (approximately three miles west of S-8). Three additional 66-inch culverts would be needed under the existing Florida Power and Light road to provide sheetflow from the Rotenberger area through these culverts (see Figure 12). One 84-inch gated culvert should be placed at the junction of the L-4 borrow canal and the Miami Canal. The existing L-4 exterior levee should be gapped at a number of locations to distribute overland flow to the adjacent portion of Water Conservation Area 3A. An additional 66-inch culvert would be placed under the FP&L road at the location where the two collector ditches meet together. This will allow a better flow capability for runoff from the north end to the south end.

V. PERFORMANCE EVALUATION OF HOLEYLAND/ROTENBERGER PROJECT COMBINATIONS

A. Operational Objectives and Constraints

1. Wet season operation (June-October): The following guidelines were applied in this evaluation:

   a. Store as much redirected flow (redirected from S-2 and S-3) as possible in the Holeyland reservoir.

   b. Operation governed by water level schedule.

   c. Pumping to storage areas to maintain schedule allowed only when runoff is generated in the basin.

   d. Pumping to Holeyland reservoir allowed whenever water level is less than 0.2 foot above regulation stage (this is to ensure that the maximum amount of water possible would be diverted away from S-7 and S-8 for better flow distribution to WCA 3A). See Figures 14 and 15 for Holeyland water level schedules which were analyzed.

   e. No pumping to the Rotenberger area during the wet season. This rule was modified after the routing results indicated that it would be too dry in the area during the wet season. A modified schedule as shown in Figure 13 was then used in this study. This schedule indicated that there would be no pumping into the Rotenberger area during June, July, and August. Some pumping will be allowed to maintain a stage of 13.5 feet msl (about 12 inches of water above ground) for September and October. This schedule will provide better water conditions for the dry season.

   f. Pumping sequence in the basin: First, Holeyland (to schedule and maximum flow-through; then S-7 and S-8; then S-2 and S-3 to the lake only during emergency flooding conditions (see Figures 16 and 17).

   g. Discharges to WCA 3A should, as a minimum, match historical discharges. The objective is to provide better distribution of flows by gravity and sheetflow rather than by pumping S-7 and S-8 only.

2. Dry season operation (November-May). The following guidelines were applied:

   a. Holeyland tapped first for water supply releases until depleted.

   b. Water supply releases terminatd when water level reaches 0.5 foot above ground surface.

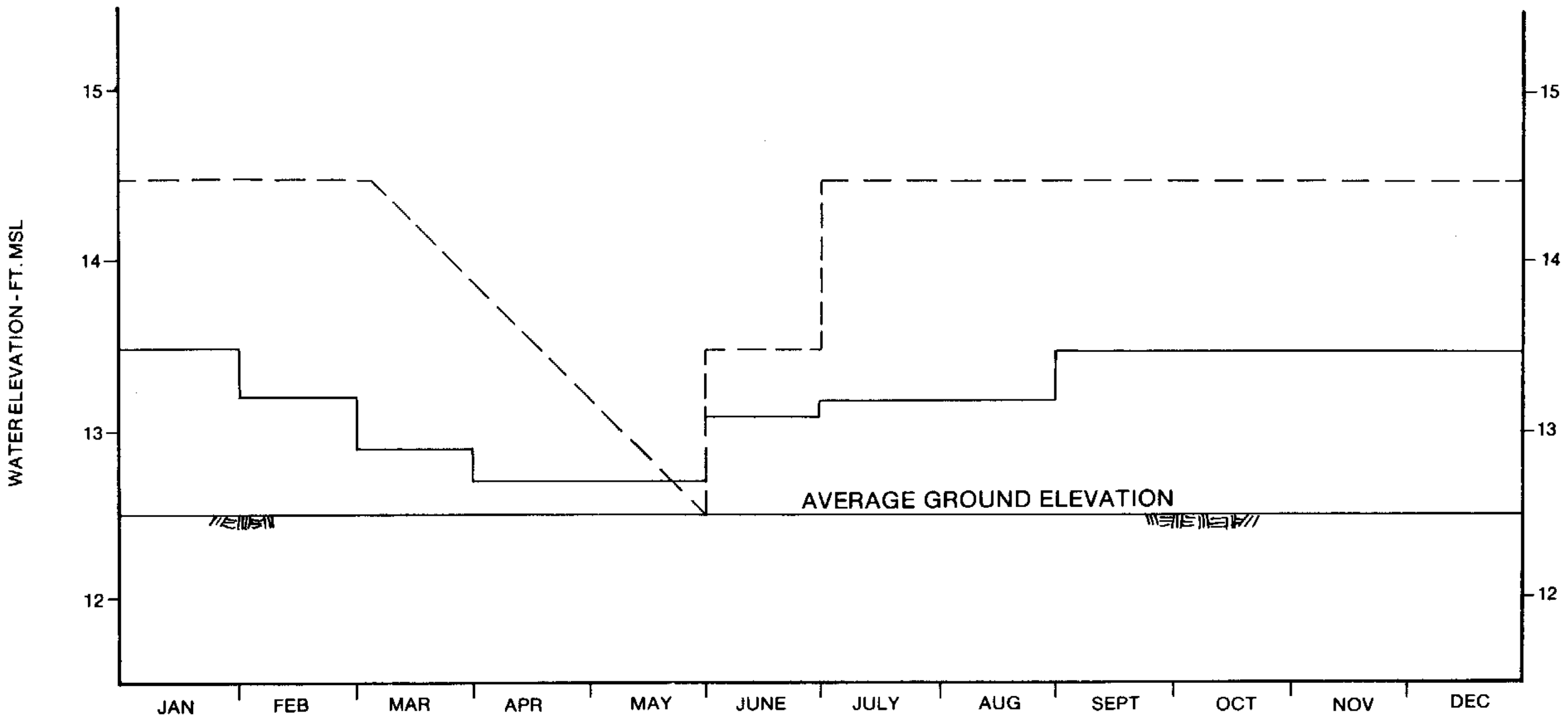


Figure 13 WATER REGULATION SCHEDULES FOR THE ROTENBERGER AREA

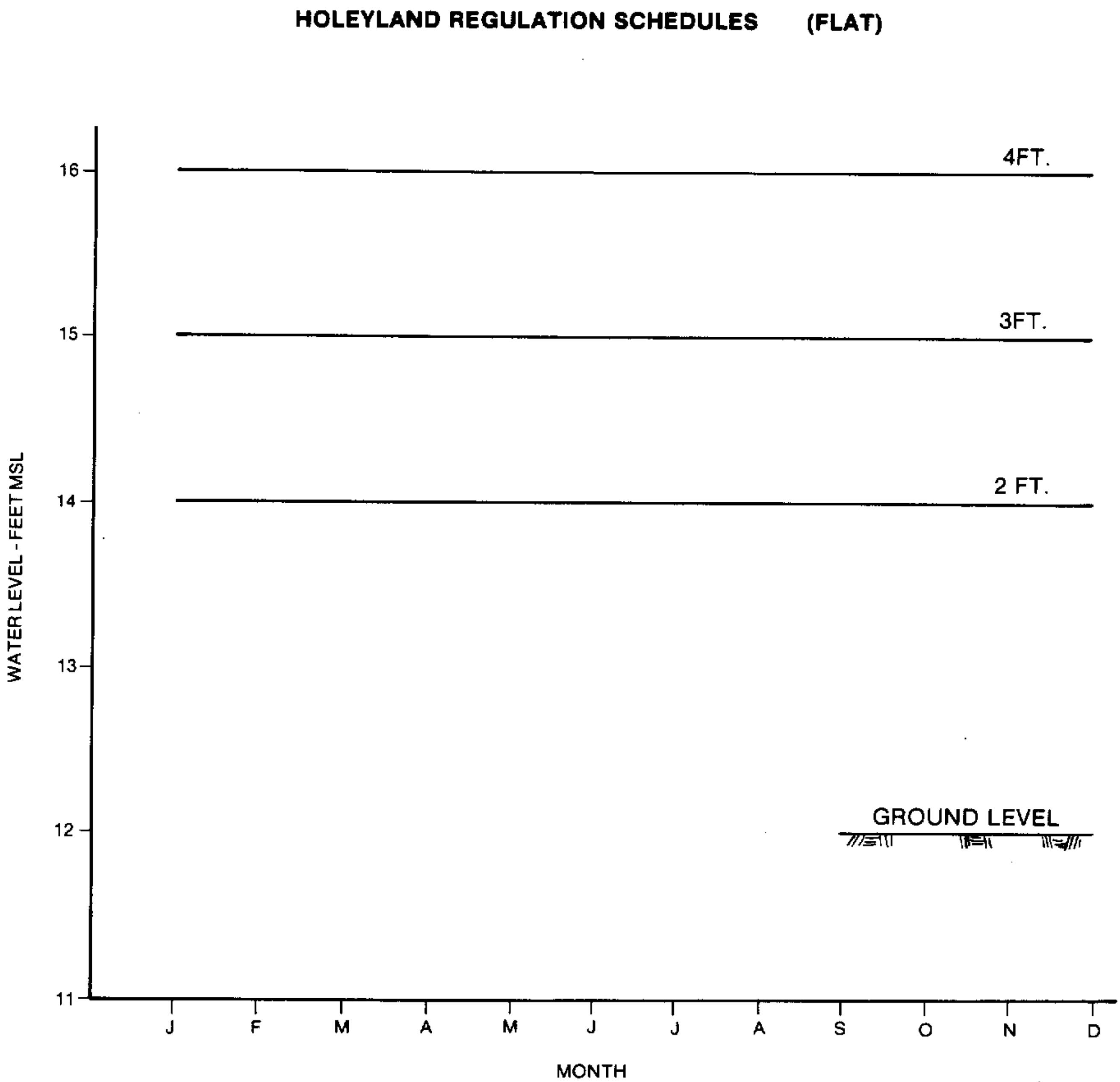


Figure 14 WATER REGULATION SCHEDULES FOR HOLEYLAND RESERVOIR

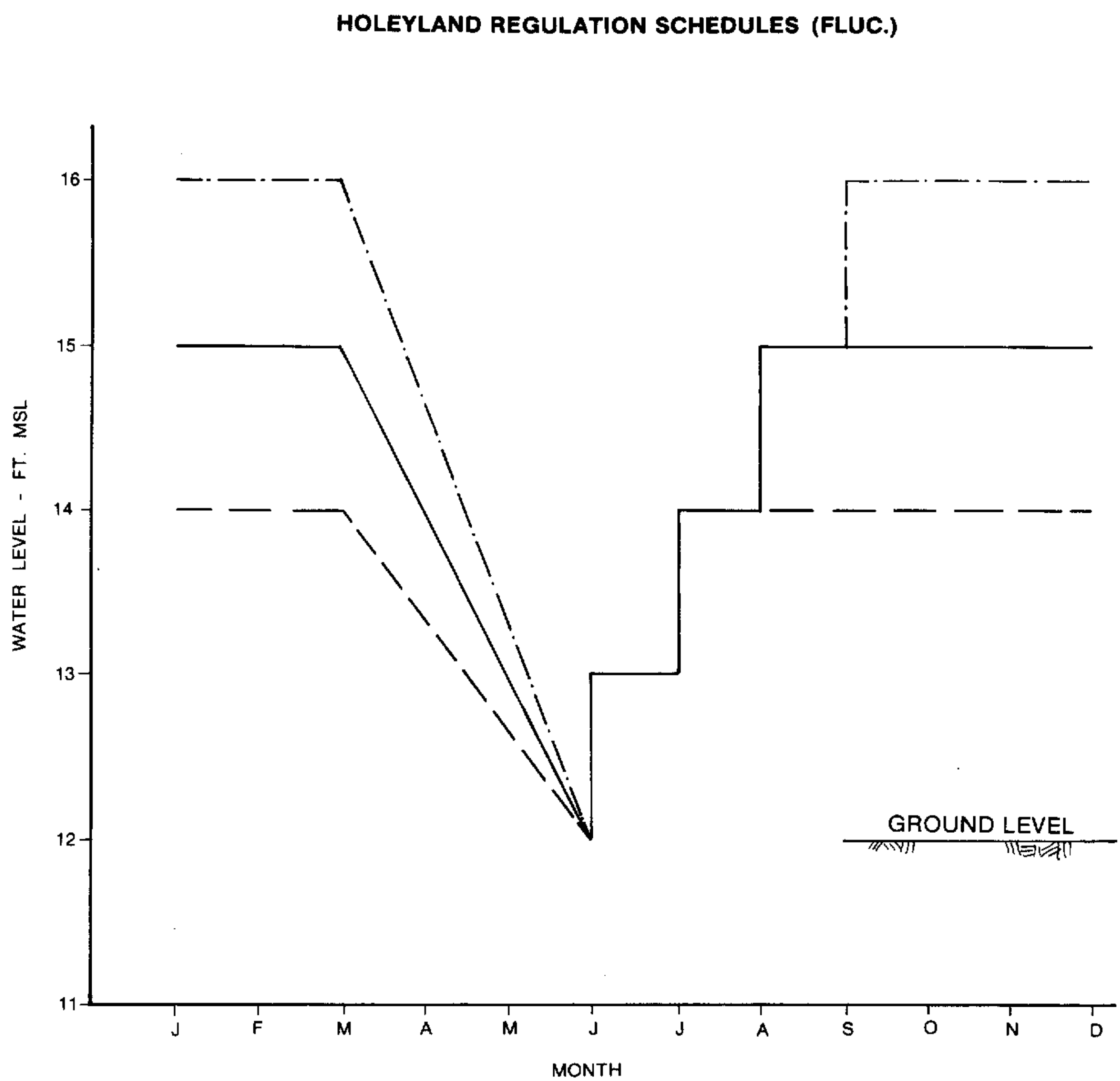


Figure 15 WATER REGULATION SCHEDULES FOR HOLEYLAND RESERVOIR

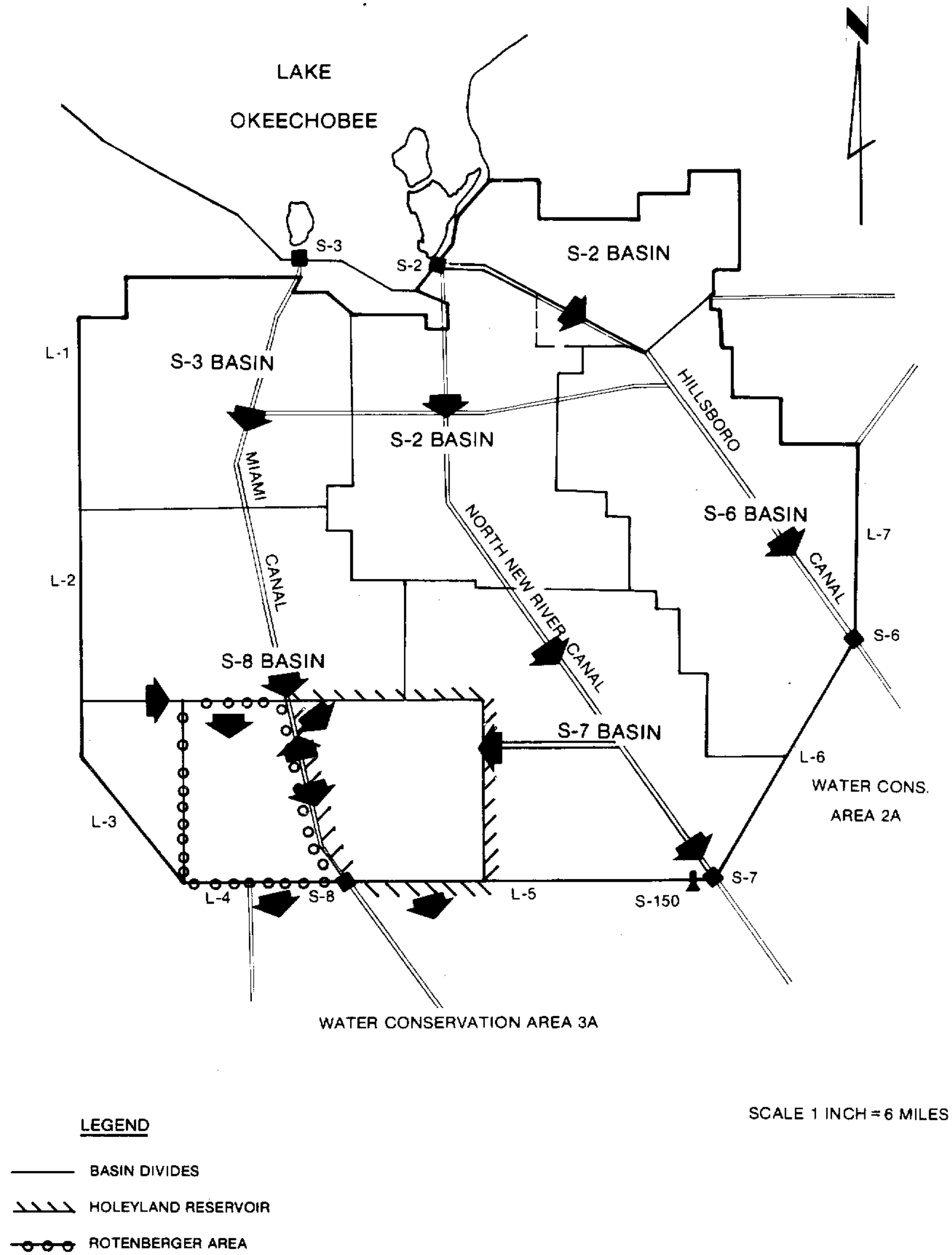


Figure 16 **LONG RANGE PLAN, MODERATE RUNOFF CONDITIONS**

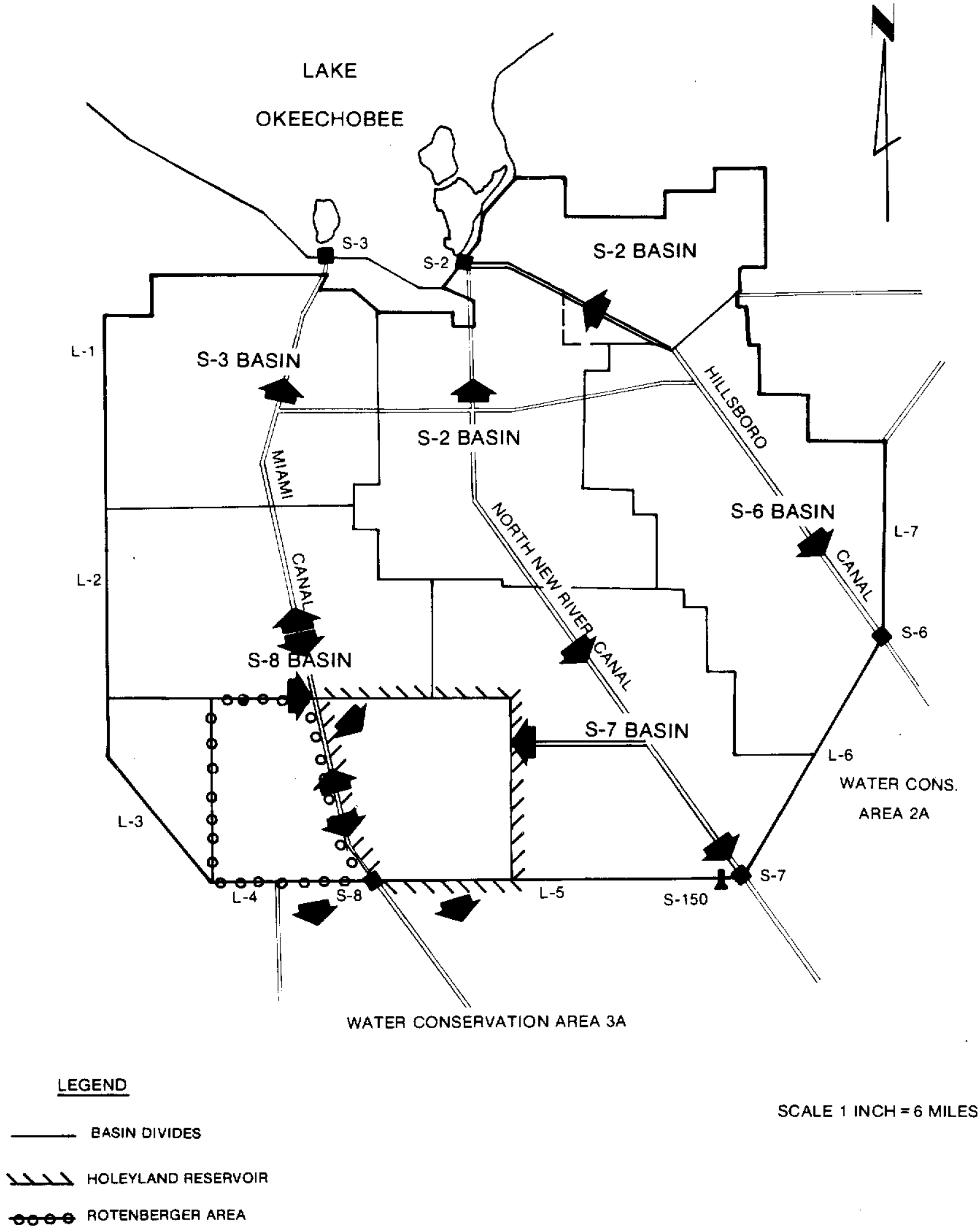


Figure 17 LONG RANGE PLAN, SEVERE RUNOFF CONDITIONS

c. Water supply releases made without regard to timing or regulation schedule, except as indicated above.

d. Outflow for purposes other than water supply releases allowed only if pool stage exceeds maximum elevation and should discharge to WCA 3A as first choice.

e. Discharges to WCA 3A should, as a minimum, match historical discharges. The objective is to provide better distribution of flows by gravity sheetflow rather than by pumping S-7 and S-8 only.

B. Evaluation Methodology

The routing procedure was developed according to the criteria mentioned above. The routing was performed on a daily basis by the simple addition and subtraction of direct rainfall on the proposed areas, evapotranspiration, seepage, irrigation withdrawals, outflow through the spillways, and inflow pumped from the North New River and the Miami Canals. The inflows from Hendry County were based on the assumption of 75 percent historical flow at the Deer Fence Canal of up to 600 cfs per day. This inflow was diverted to the Rotenberger area via an intake located on the east bank of L-3 near the Deer Fence Canal.

The routing procedure allowed the deliveries for irrigation to be equal to the irrigation demand on all days except when the stage in the Holeyland was below 0.5 feet above ground or the demand exceeded 600 cfs. Below these, any deficits were to be made up by deliveries from Lake Okeechobee. The routing period used in this study was from January 1, 1963 through December 31, 1981, due to the availability of data.

C. Impacts on Holeyland and Rotenberger Areas

The following scenarios were analyzed in this study:

Water Regulation Schedules

Holeyland (Fig. 14, 15	Rotenberger Tract (Fig. 13)
2 ft. flat schedule	0-12 inches
3 ft. flat schedule	0-12 inches
4 ft. flat schedule	0-12 inches
2 ft. fluctuated schedule	0-12 inches
3 ft. fluctuated schedule	0-12 inches
4 ft. fluctuated schedule	0-12 inches
2 ft. fluctuated schedule	0-24 inches
2 ft. fluctuated schedule	0-24 inches*

*Area includes Manley Ditch

Figures 16 and 17 illustrate runoff flow directions in the EAA for the proposed plan under moderate and extremely wet conditions.

1. Rotenberger area

Two water regulation schedules were analyzed. One was based on a 0-12 inch maximum water depth with no water supply releases from the area, the other on a 0-24 inch maximum water depth to provide recycling water for local demand. The projected water levels in the Rotenberger tract under the 0-1 foot schedule varies between 12.0 feet msl to 13.5 feet msl under most cases. If there was additional inflow from Hendry County, this could be managed at the intake structure to maintain a desired water level in the Rotenberger tract. The results of this study also indicate that the different regulation schedules used in the Holeyland area do not affect the stage in the Rotenberger area. The projected water levels under the last two scenarios (in which one area included the Indian Reservation north to Manley Ditch) are almost the same under the proposed system. The water levels fluctuated between 12.5 and 14.6 feet msl under the simulated conditions, with the exception of the wet conditions similar to 1968 and 1969. A limited amount of additional supplemental water may be required for muck fire prevention during the month of April (6,000 AF for 1967, 1971, and 1981 rainfall conditions). The average amount of supplemental water required under the 0-12 inch schedules are 2,400, 4,400 and 8,000 AF for February, March, and April. This difference may be due to the reduction in storage under this schedule.

Holeyland area

The projected water levels in the Holeyland varied from near ground level to the top of the schedule under simulated conditions. The results also indicated that the proposed outlet structures would be capable of maintaining stages in the area without causing excessively high water levels. The water levels reach the top of the schedule most of the time under the flat schedule, and the area would not be as dry as under the fluctuated schedule. The results under the fluctuated schedule indicated that the top of the schedule would not be reached for the rainfall conditions similar to the years 1964, 1967, 1972, and 1981.

2. Water quality benefits of the Holeyland marsh

   a. Wetland nutrient removal capabilities

      Florida freshwater wetlands are well known for their nutrient removal capabilities. Studies of wastewater renovation on Florida mixed hardwood swamps and marshes have shown phosphorous removal to be 97-98 percent effective while nitrogen concentrations showed about 89 percent removal (Boyt et. al., 1976; Dolan et. al., 1978). Marshlands are well suited for receiving and storing large volumes of nutrient laden water for several reasons. Wetlands rank as one of the world's most productive ecosystems (Bayley and Burns, 1974; Carter et. al., 1973; Niering, 1973; Richardson, 1979). The marsh's high productivity is a result of its ability to filter and trap nutrients from the water and store them within plant vegetation, leaf litter and soils. As a result, marshlands act as a natural water quality filter and nutrient sink absorbing and storing excess inorganic nutrients within the ecosystem (Odum, 1978). Over the past decade numerous research projects have investigated the nutrient removal capabilities of southern marsh ecosystems. Freshwater wetlands have been shown to remove pollutants, sediments, and nutrients in river swamps (Wharton, 1970; Kitchens et. al., 1975); Patrick et. al., 1976; Yarbro et. al., 1981; Dierberg, 1981), hardwood swamps (Boyt, 1976), cypress domes (Ewel and Odum, 1978; Fritz and Helle, 1981), freshwater marshes (Shih and Hallet, 1974; Dolan, 1978; Zoltek et. al., 1979; Federico et. al., 1981; Davis, 1981), and the Everglades sawgrass marsh (Steward and Ornes, 1975; Gleason, 1974; McPherson, et. al., 1976; Davis and Harris, 1978; Swift, 1981; Davis, 1982). Recent work in Water Conservation Areas 2A and 3A have sown the effectiveness of the Everglades marsh in the uptake of nutrients resulting from agricultural surface runoff. WCA 2A is a 173 square mile (448 km^2) sawgrass marsh located in the western portions of Palm Beach and Broward Counties. Water is supplied to the area primarily through the three S-10 structures located in the northeast section of the marsh (Figure 18). For more than 22 years (the S-10's became operational in 1961), these structures have discharged nutrient enriched agricultural surface water across the WCA 2A marsh. Preliminary work conducted by Gleason (1974) showed that WCA 2A had a "purifying or kidney effect" on nutrients discharged across the marsh. Inorganic nutrients were reduced to background levels (generally below detection limits) within a 3-4 mile (4.8-6.4 km) distance from S-10 inflows. Davis (1978) has collected 7 years of data concerning the nutrient uptake capabilities of the WCA 2A sawgrass/cattail vegetation and leaf litter downstream from the S-10D discharge structure. Data collected in this study include detailed profiles of nitrogen and phosphorous concentrations as water is discharged across the marsh (these data are presented in a later section of this report).

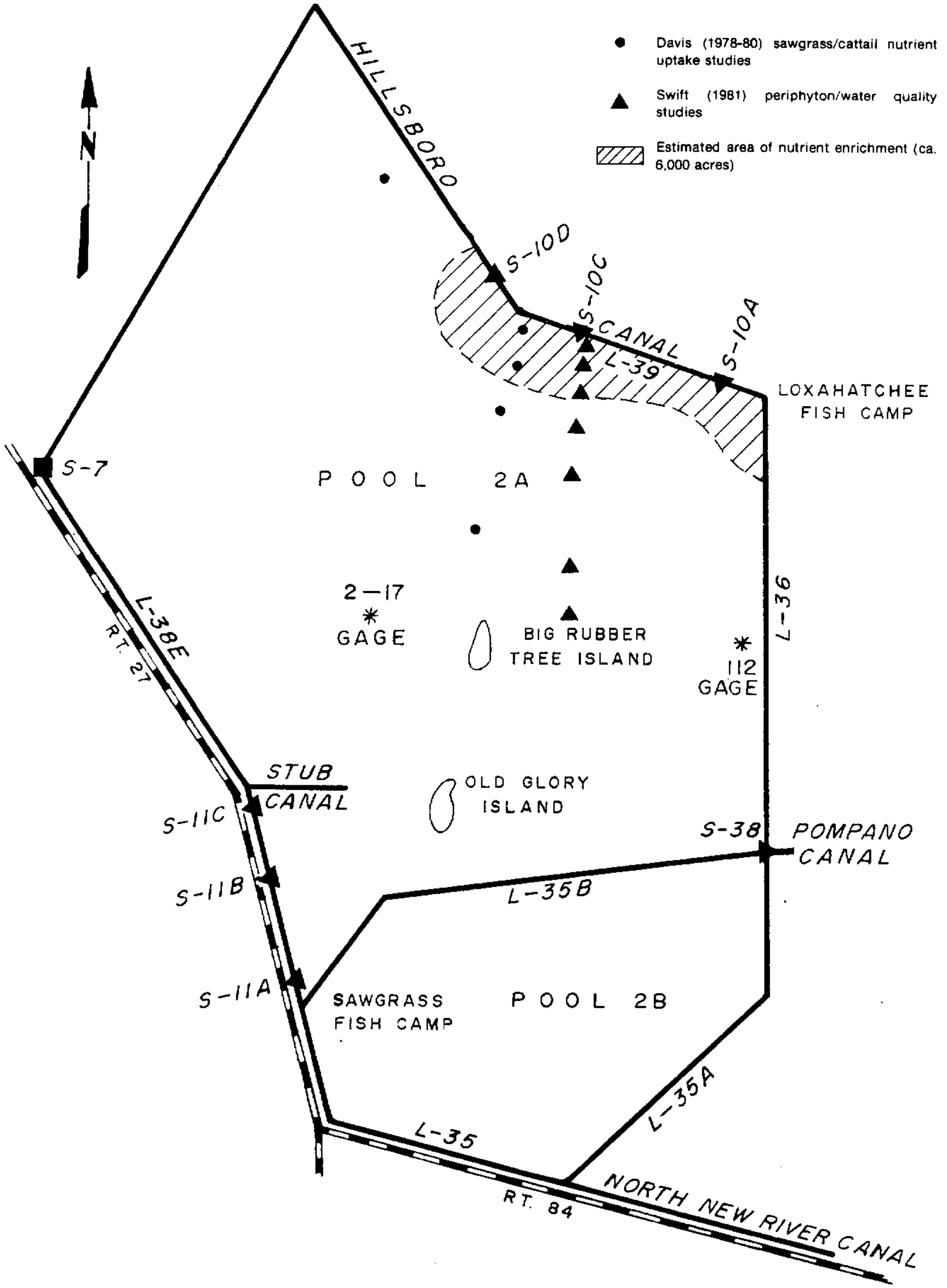


Figure 18 WATER CONSERVATION AREA 2A NUTRIENT UPTAKE SAMPLING LOCATIONS AND ESTIMATED AREA OF NUTRIENT ENRICHMENT

Average flow weighted discharges into the marsh during 1978-80 through S-10D were 1.48 mg/l inorganic N, 0.101 mg/l total PO_4, and 0.079 mg/l ortho-PO_4. Nutrient inflows were reduced to background levels (0.02 mg/l inorganic N, 0.025 mg/l Total PO_4 and 0.002 mg/l ortho-PO_4) at a distance of approximately 4.5 km (2.7 miles) from S-10D. Element budgets show that 98.6 percent, 75.2 percent and 97.4 percent of the total input of inorganic N, total PO_4, and ortho-PO_4 entering the marsh through S-10D were removed from the water.

Davis' work on marsh vegetation nutrient uptake showed that increased nutrients and water depth stimulate the development of a cattail dominated marsh rather than a natural sawgrass marsh. Under high N and P concentrations, cattail vegetation was found to actively uptake and store marsh water nutrients to a greater degree than sawgrass vegetation. Marsh leaf litter (detritus) was shown to be as important as living vegetation for the uptake of nutrients during the first year of decomposition. Leaf litter nutrient uptake was much higher in zones of nutrient enrichment. Davis' (1982) radiophosphorous (^{32}P) studies in WCA 2A showed that marsh organic peat soils are a major nutrient sink for phosphorous. More than one-half of the labeled inorganic PO_4 was incorporated into the peat soils within 10 days after its introduction into the marsh water column.

Swift (1980) has conducted a parallel study monitoring the impacts of nutrients on the Everglades periphyton (algae) community. Results of 1978-79 showed nutrients to impact the marsh for a distance of 4.5 km (2.8 miles) south of the S-10C discharge structure in WCA 2A. Beyond this point, nutrients, algae species composition and growth rates returned to background levels. Figure 19 presents periphyton growth rates and periphyton phosphorous content for the summer of 1978. Flow weighted concentrations of inorganic N, total PO_4 and ortho-PO_4 discharged into the marsh through S-10C during 1978 averaged 0.68 mg/l inorganic N, 0.054 mg/l total PO_4, and 0.027 mg/l ortho-PO_4, respectively (Millar, 1981). Nutrients were reduced to background levels of 0.02 mg/l inorganic N, 0.012 mg/l total PO_4, and 0.002 mg/l ortho-PO_4 at a distance of 4.5 km (2.8 miles) into the marsh. This represents N and P removals of 97 percent for inorganic N, 78 percent for total PO_4, and 93 percent for ortho-PO_4. Marsh water phosphorous was shown to be the major factor controlling algae growth rates in the marsh, while major ion concentrations and pH governed periphyton species composition. Nutrient enriched portions of the marsh supported a "specialized" community of pollution tolerant blue-green algae (<u>Microcoleus</u>) and diatoms replacing the "normal" Everglades periphyton. Concentrations of N and P within the water column, soils and algal plant tissues were low in comparison to literature values and suggest nutrient limitation at interior WCA 2A sites. It is unknown whether observed shifts in algal species composition and increases in

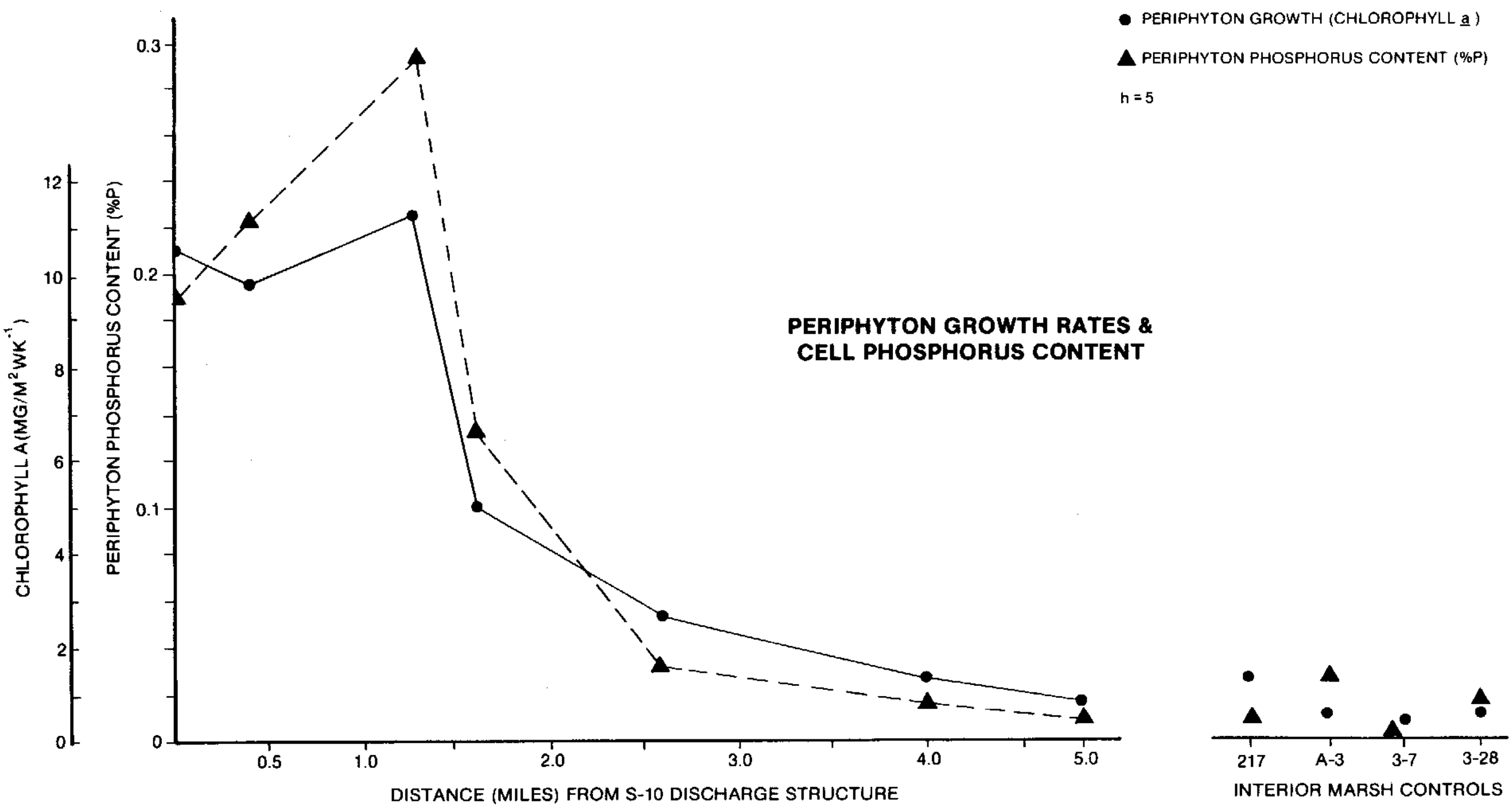


Figure 19 AVERAGE PERIPHYTON GROWTH RATES AND CELL PHOSPHORUS CONTENT SOUTH OF THE S-10C DISCHARGE STRUCTURES, WCA-2A, JUNE-AUGUST, 1978

periphyton and cattail biomass are detrimental to upper trophic level marsh organisms. However, diel studies of dissolved oxygen concentrations in nutrient enriched areas of the marsh showed significantly lower concentrations in comparison to interior WCA 2A sites during 1978-79 (Figures 20 and 21). As a result, low D.O. may limit the diversity of aquatic life in nutrient enriched portions of the marsh favoring those species adapted to low D.O. tensions (e.g., mosquito fish, flagfish, bowfins, gars, etc.).

In summary, water quality investigations in WCA 2A demonstrate well the nutrient removal capabilities of the marsh ecosystem. Although the three S-10 structures have been in operation for over 22 years, nutrient impacts upon the marsh have been confined to a relatively small area 4-4.8 km (2.5-3.0 miles) distance south of the S-10's.

Similar water quality monitoring efforts were conducted in WCA 3A during the summer of 1982 to trace the uptake of nutrients by the marsh. Two different transect locations were monitored on four dates (Figure 22). These sites were (a) and east-west transect (a total of 12 sites) perpendicular to the newly constructed "environmental enhancement" structure, S-339 located on the Miami Canal (C-123) and (b) a transect beginning on C-60 (4 sites) extending eastward into the marsh in the direction of the 3-2 (deer) gauge. Measurement of conservative parameters (chlorides, sodium, conductivity) allowed canal water movement to be traced within the marsh. Collection of nutrient samples and the measurement of periphyton (algae) growth rates on glass slides allowed a comparative assessment of nutrient uptake across the marsh. Preliminary results showed conservative parameters to impact the marsh at least a distance of 6.4 km (4 miles) east and west of C-123. When S-339 was closed and canal water was forced across the marsh, inorganic N was reduced to background levels 3.2 km (2 miles) west and 0.4 km (1/4 mile) east of the structure, while total PO_4 impacted the marsh a distance of 1.6 km (1 mile) east and west of C-123 (Figures 23 and 24). Algae growth rates were reduced to background levels within 1.6 km (1 mile) west of S-339 (Figure 25). Similar nutrient uptake and algal growth rate trends were noted along the C-60 transect as nutrients were discharged across the marsh by pump stations S-140 (Figures 26, 27, and 28).

b. Projected nutrient loadings to Holeyland

Projected annual nutrient loadings into the Holeyland are based on:

(1) Calculated annual inflows into the Holeyland based on historical data.

(2) Average annual flow-weighted nutrient concentrations from the Miami and North New River Canals.

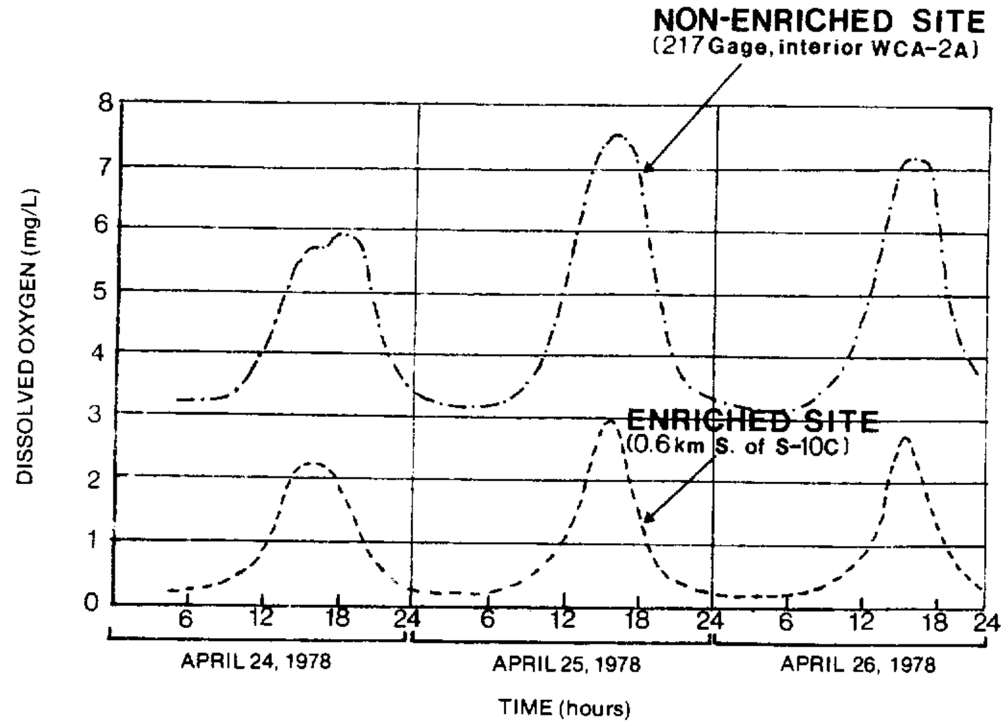


Figure 20 DIURNAL OXYGEN CURVES AT NUTRIENT ENRICHED AND NON-ENRICHED WCA-2A MARSH SITES, APRIL, 1978

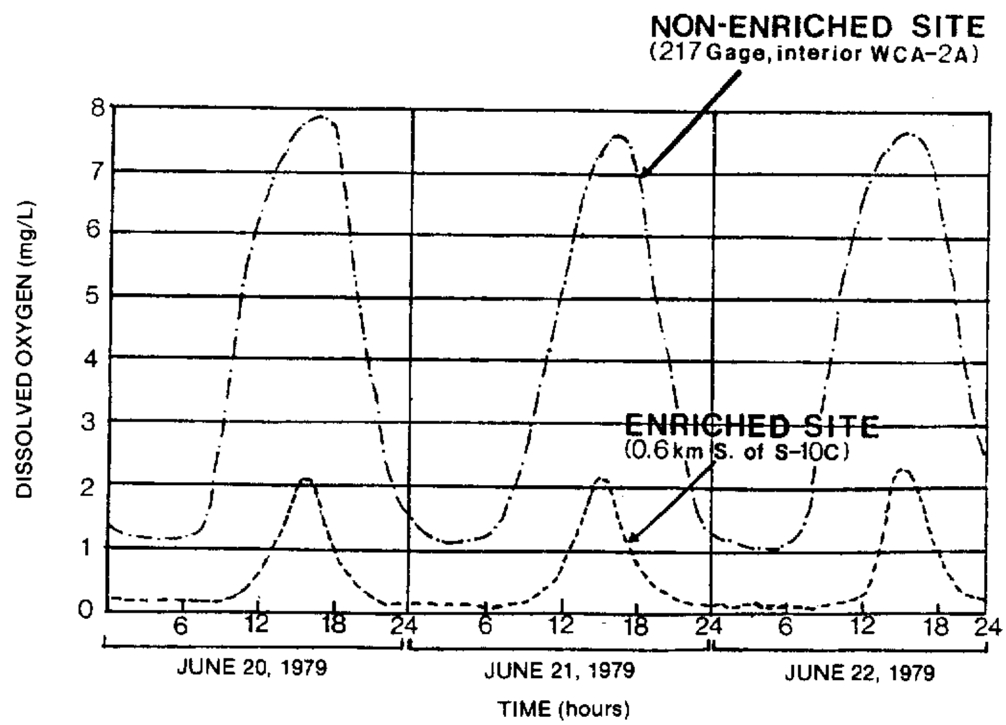


Figure 21 DIURNAL OXYGEN CURVES AT NUTRIENT ENRICHED AND NON-ENRICHED WCA-2A MARSH SITES, JUNE, 1979

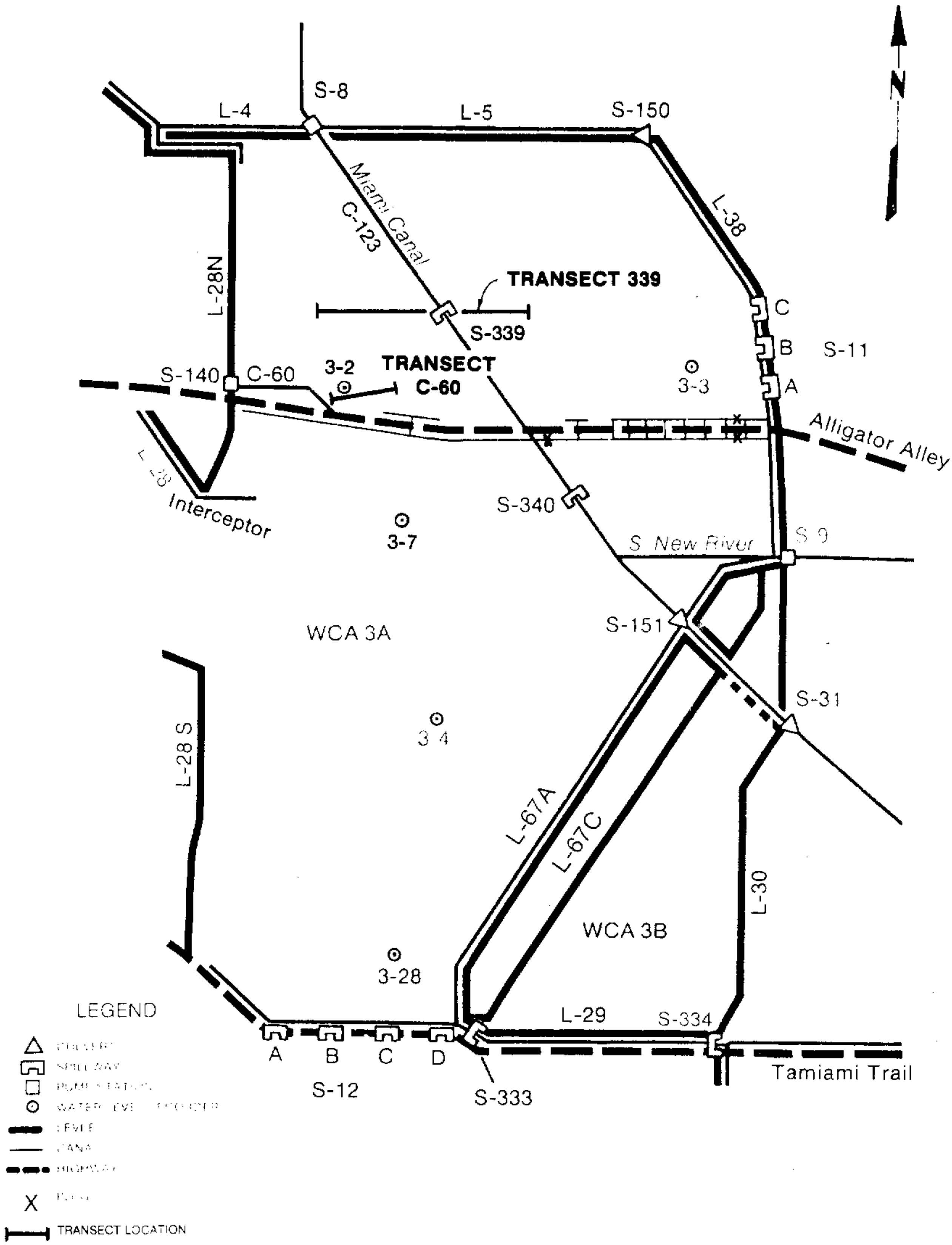


Figure 22 LOCATION OF WATER QUALITY TRANSECTS 339 AND C-60, WCA-3A, JUNE-AUGUST 1982

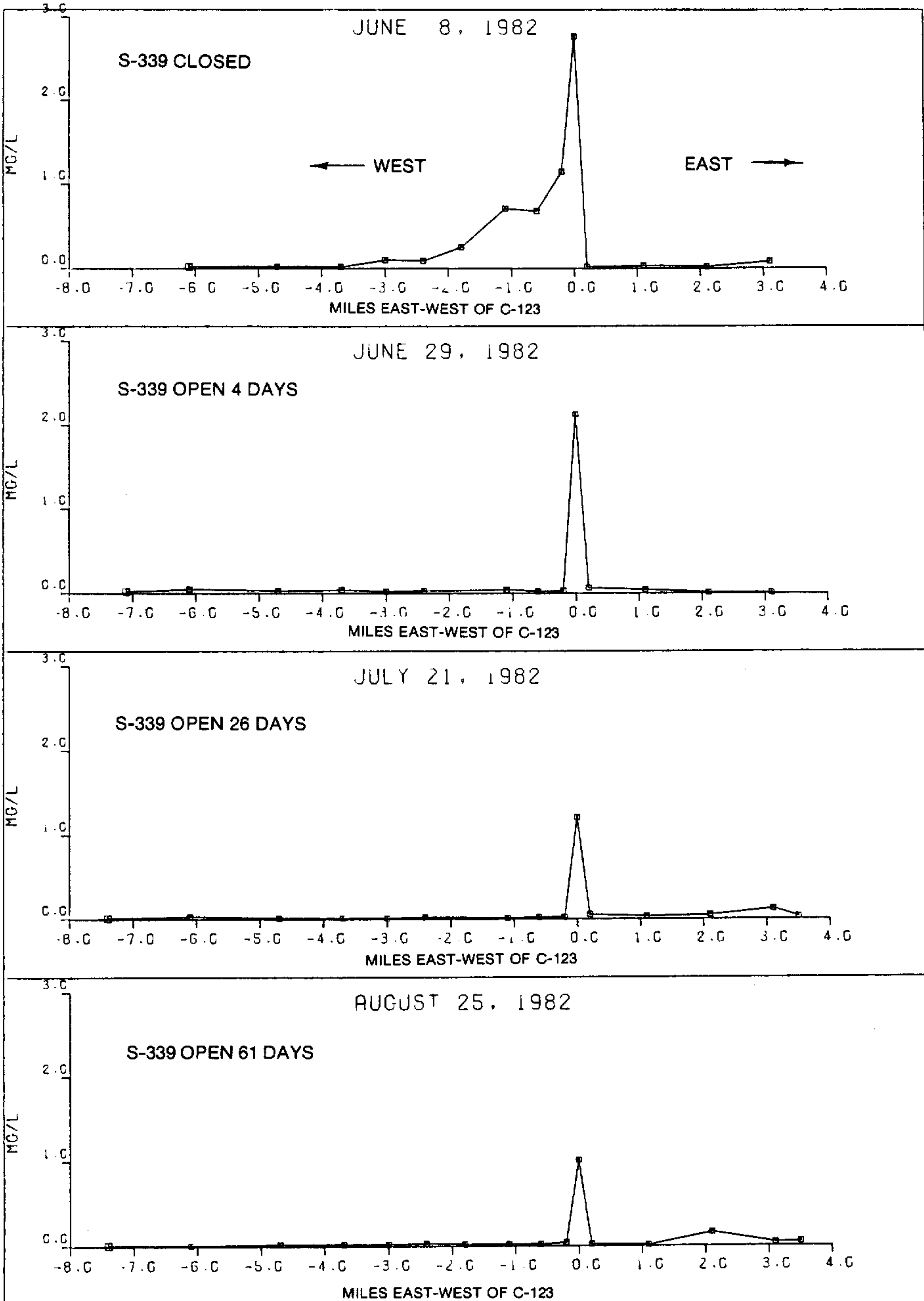


Figure 23 INORGANIC NITROGEN (NOX - NH4) TRANSECT 339

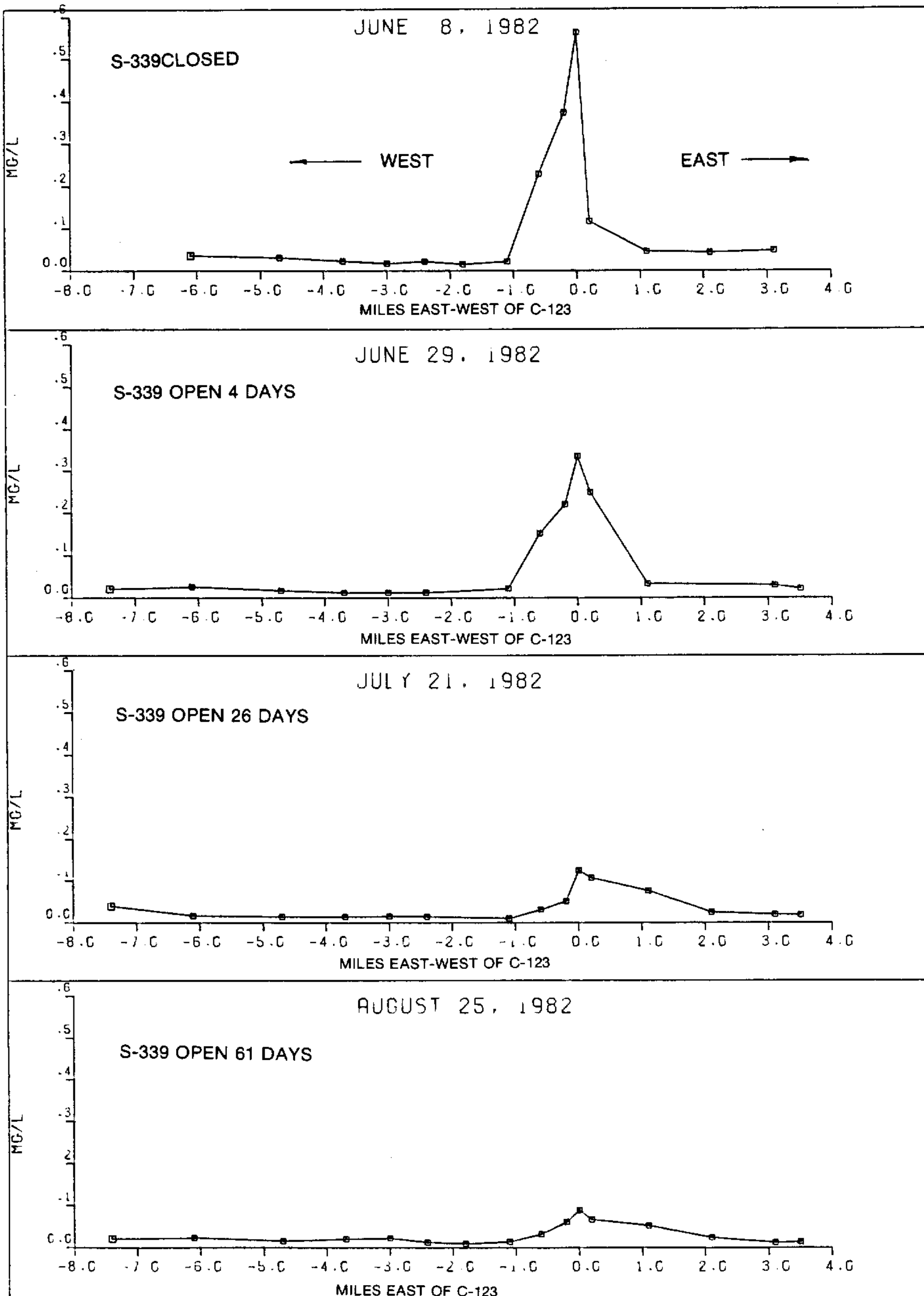


Figure 24 TOTAL PO4 TRANSECT 339

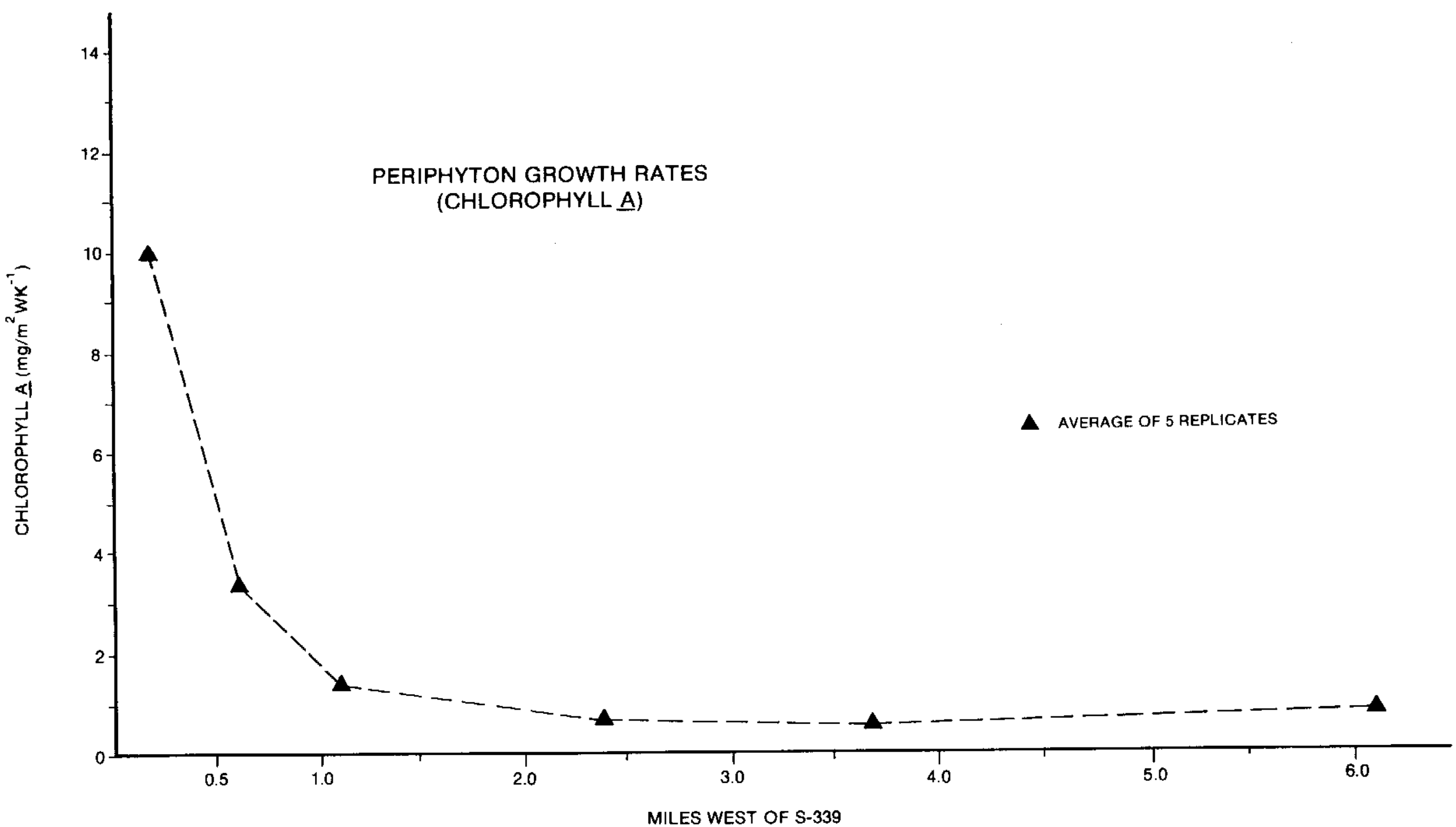


Figure 25 PERIPHYTON GROWTH RATES WEST OF S-339, JULY-AUGUST, 1982

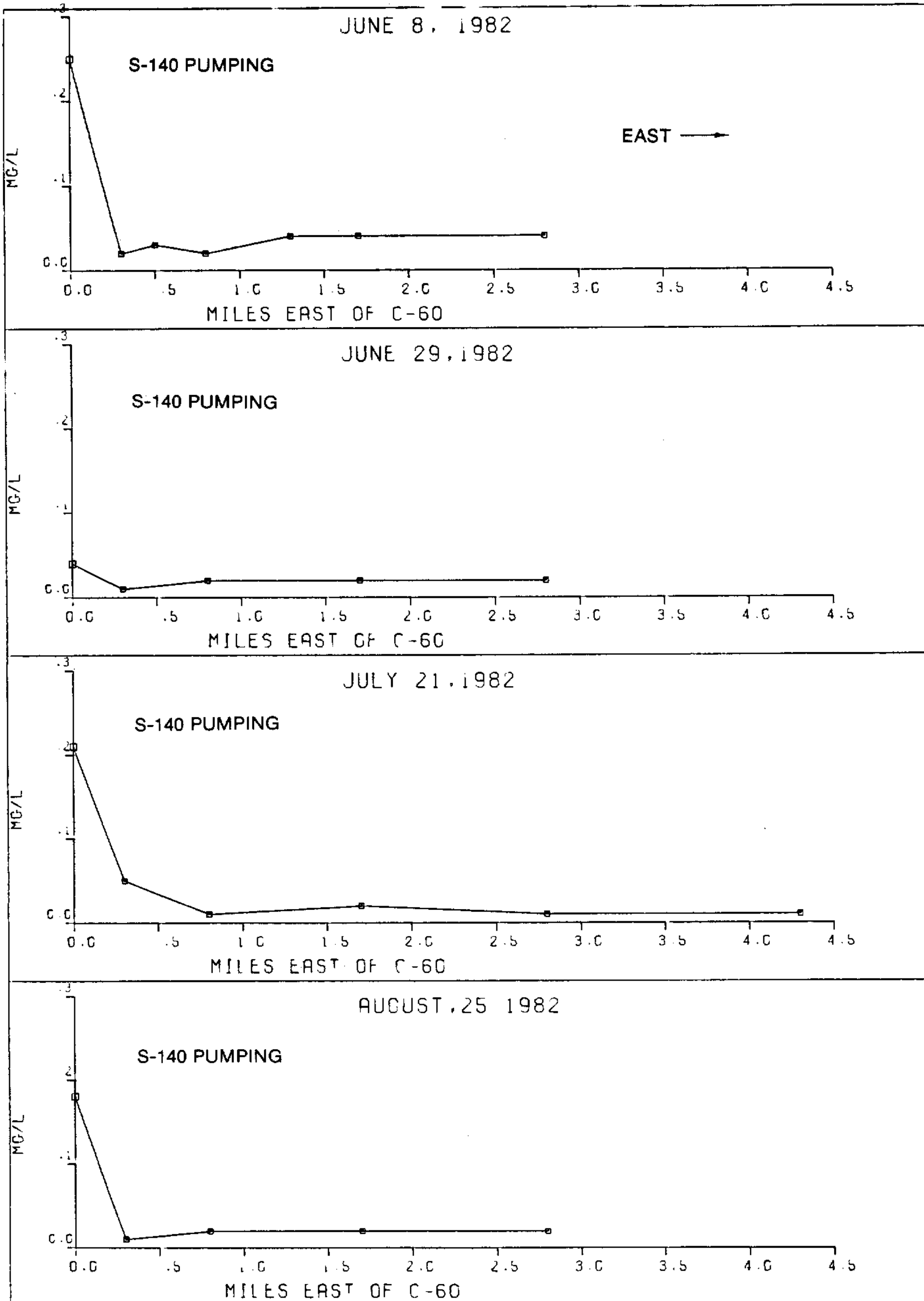


Figure 26 INORGANIC NITROGEN C-60 TRANSECT

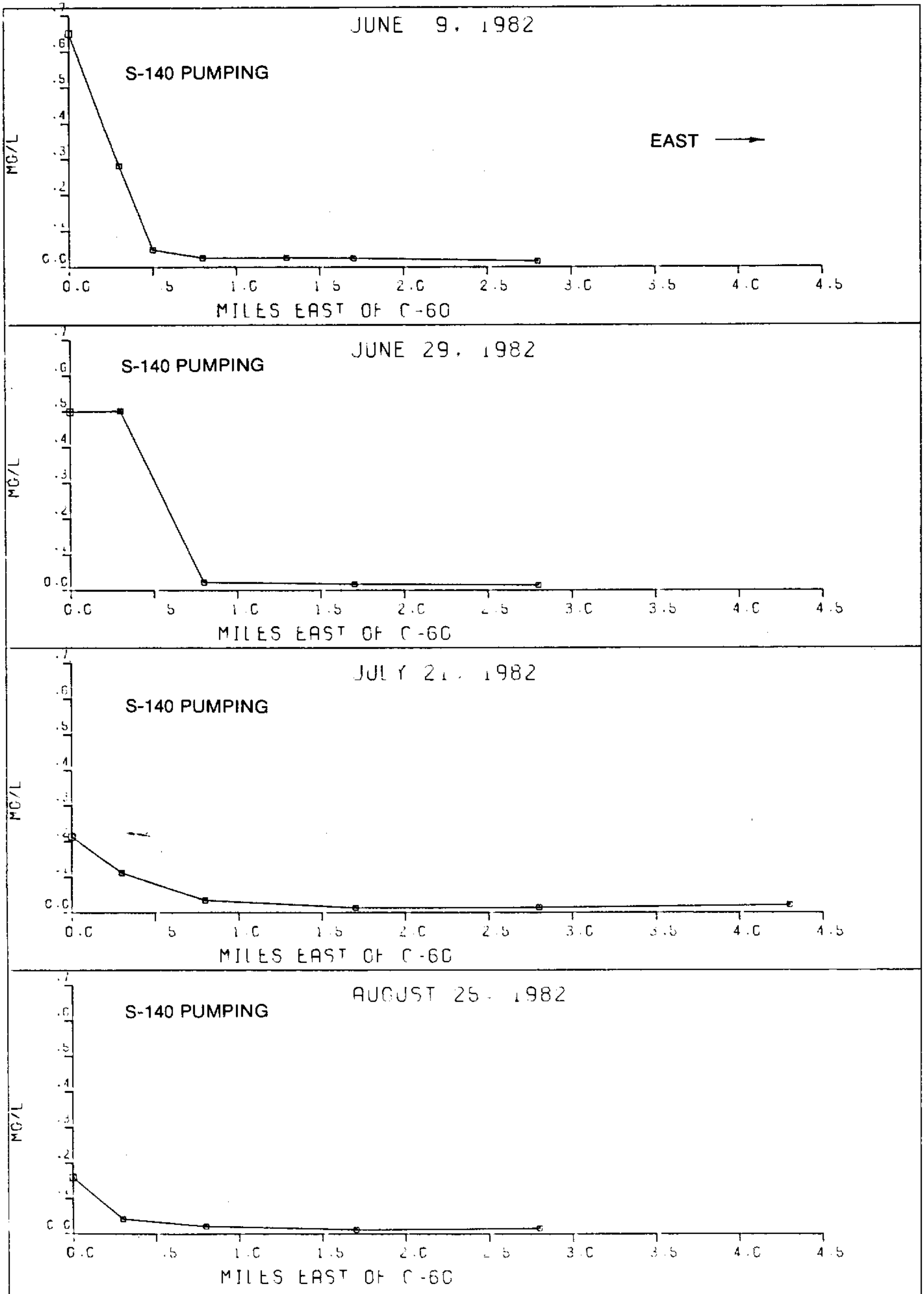


Figure 27 TOTAL PO4 TRANSECT C-60

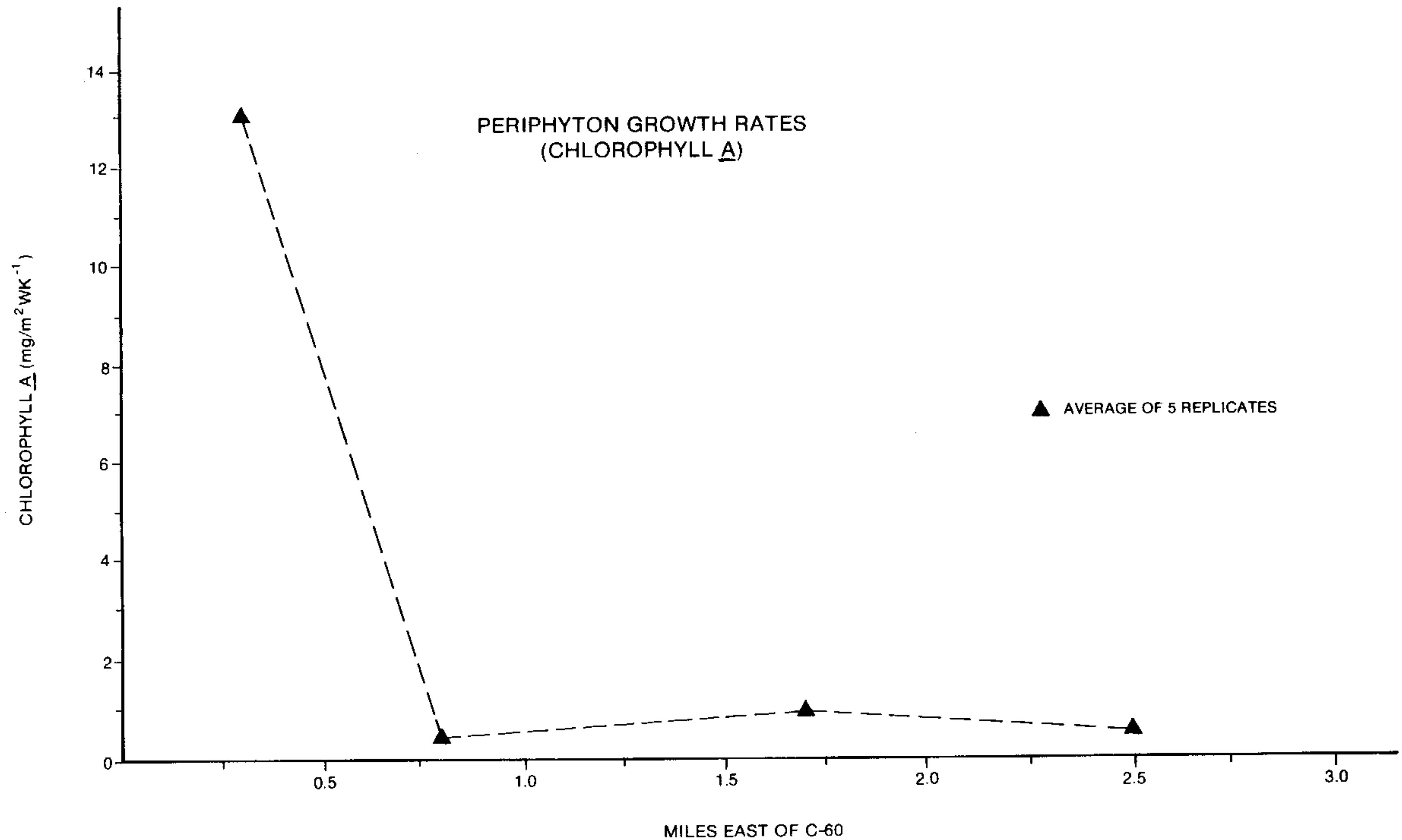


Figure 28 PERIPHYTON GROWTH RATES EAST OF C-60, JULY-AUGUST, 1982

(3) Nutrient uptake profiles in WCA 2A as a result of S-10D nutrient enrichment.

(4) Estimates of nutrient impacts on WCA 2A vegetation based on aerial photography and nutrient uptake profiles.

Annual inflows into the Holeyland are based on historical flow data from the S-2 and S-3 pump basins, the Miami Canal basin at pump station S-8, and from the North New River Canal basin at pump station S-7 for the period of record 1963-81. Computer estimates predict that had the Holeyland project been operational over the past 18 years, inflows into the area would average on an annual basis about 102,400 acre feet from the Miami Canal and 144,400 acre feet from the North New River Canal. These averages are similar to inflows predicted for the 1978-81 record for which water quality information exists. Predicted inflows into the Holeyland during 1978-81 would have averaged 100,200 and 146,900 acre feet, respectively, from the Miami and North New River Canals.

Flow-weighted mean nutrient concentrations into the Holeyland were estimated from water chemistry samples collected every two weeks at pump stations S-7 and S-8 during the period of record from 1978-1981. Results show that nutrient concentrations in S-8 water were similar to S-7 during 1978-80 (Table 17).

Nutrient concentrations in the North New River Canal (S-7) increased considerable during the 1981 drought in comparison to 1978-80. In contrast, nutrients in the Miami Canal (S-8) decreased during 1981 as compared to the previous three years of record (Table 17). Although nutrient concentrations within both canals appear to vary in response to annual rainfall events, the 1978-81 period of record provides the best available estimate of mean annual nutrient concentration during an average year. These concentrations are provided in the right hand column of Table 17.

Mean annual nutrient loadings to the Holeyland were estimated by multiplying predicted average inflows for the 18-year period of record by average flow-weighted nutrient concentrations for 1978-81. These loadings are compared with annual inputs to WCA 2A through the S-10 structures during 1978-81 in Table 18.

Projected areas of nutrient impact and nutrient uptake within the Holeyland marsh were based on nutrient profile studies conducted in WCA 2A during 1976-80. Water quality samples were collected from four sites located within the pathway of water flow into WCA 2A via S-10D (Figure 1). Mean annual nutrient concentrations at the four sites and S-10D showed that inorganic nutrients were essentially reduced to background levels within 4.5 km (2.8 miles) distance from the inflows (Figures 29 and 30).

Each year ortho-PO_4 showed the largest reduction in concentration as water moved across the marsh. Concentrations dropped to background levels (0.010 mg ortho-PO_4/l) within 4.5 km (2.8 miles)

TABLE 17

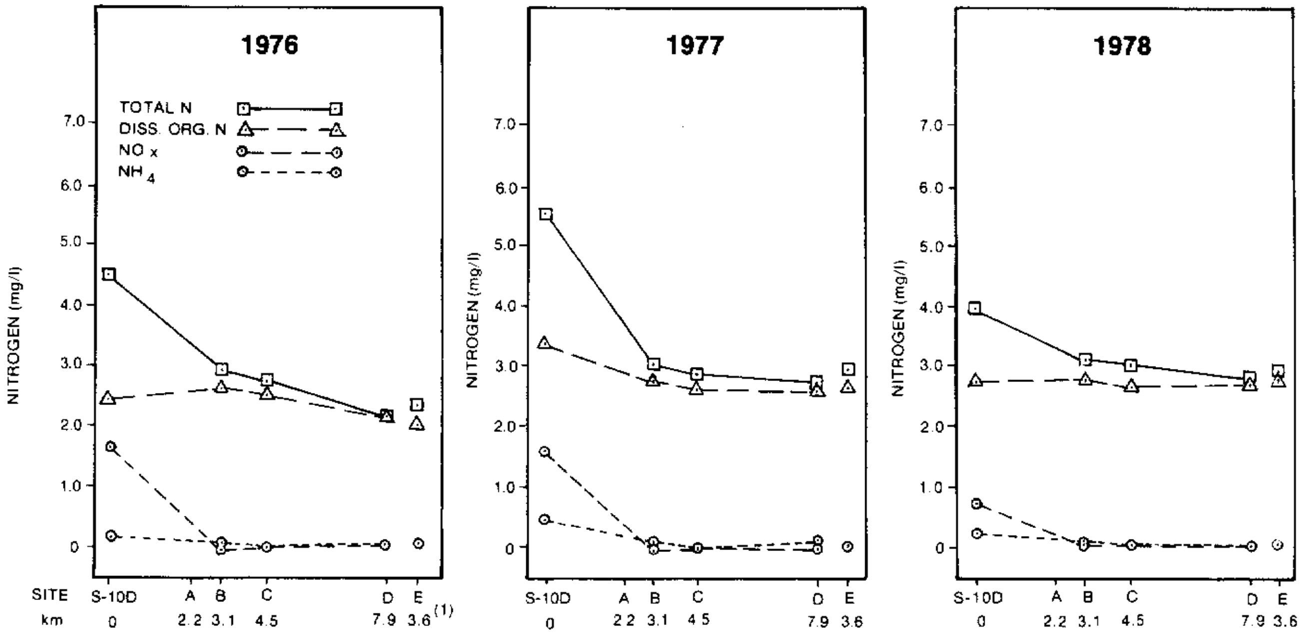
FLOW-WEIGHTED MEAN NUTRIENT CONCENTRATIONS (mg/l) IN S-7 AND S-8 WATER

		1978-80	1981	1978-81
TPO_4	S-7	.063	.262	.091
	S-8	.065	.035	.063
OPO_4	S-7	.030	.288	.066
	S-8	.024	.020	.024
Tot N	S-7	4.115	6.567	4.461
	S-8	4.057	3.152	3.996
NO_X	S-7	1.199	3.423	1.513
	S-8	1.270	.773	1.236
NH_4	S-7	.092	.125	.097
	S-8	.074	.059	.073

TABLE 18

MEAN ANNUAL NUTRIENT LOADING (TONNES) INTO WCA 2A THROUGH THE S-10 STRUCTURES COMPARED TO PREDICTED LOADINGS INTO THE HOLEYLAND

Parameter	Loading to WCA 2A through S-10 Structures	Loading to Holeyland from North New River Canal	Loading to Holeyland from Miami Canal
TPO_4	36.58	16.20	7.95
OPO_4	27.71	11.75	3.03
Tot N	1,674.49	794.28	504.48
NO_X	359.82	269.39	156.04
NH_4	93.78	17.27	9.22
NO_X+NH_4	453.60	286.66	165.26



(1)Due to ground elevation,Site E was outside the flow route of S-10D water and therefore was subjected to background nutrient concentrations similar to Site D.

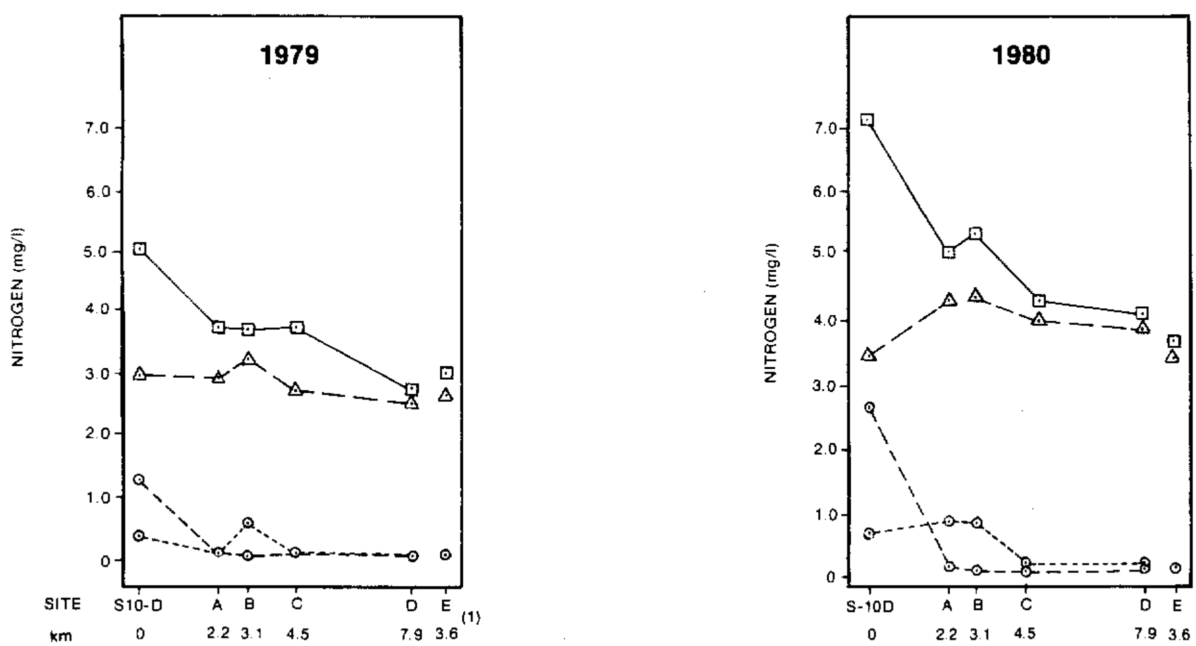


Figure 29 MEAN ANNUAL NITROGEN CONCENTRATIONS (mg/l) IN SURFACE WATER IN WATER CONSERVATION AREA 2A IN RELATION TO DISTANCE (km) FROM INFLOW STRUCTURE S-10D.

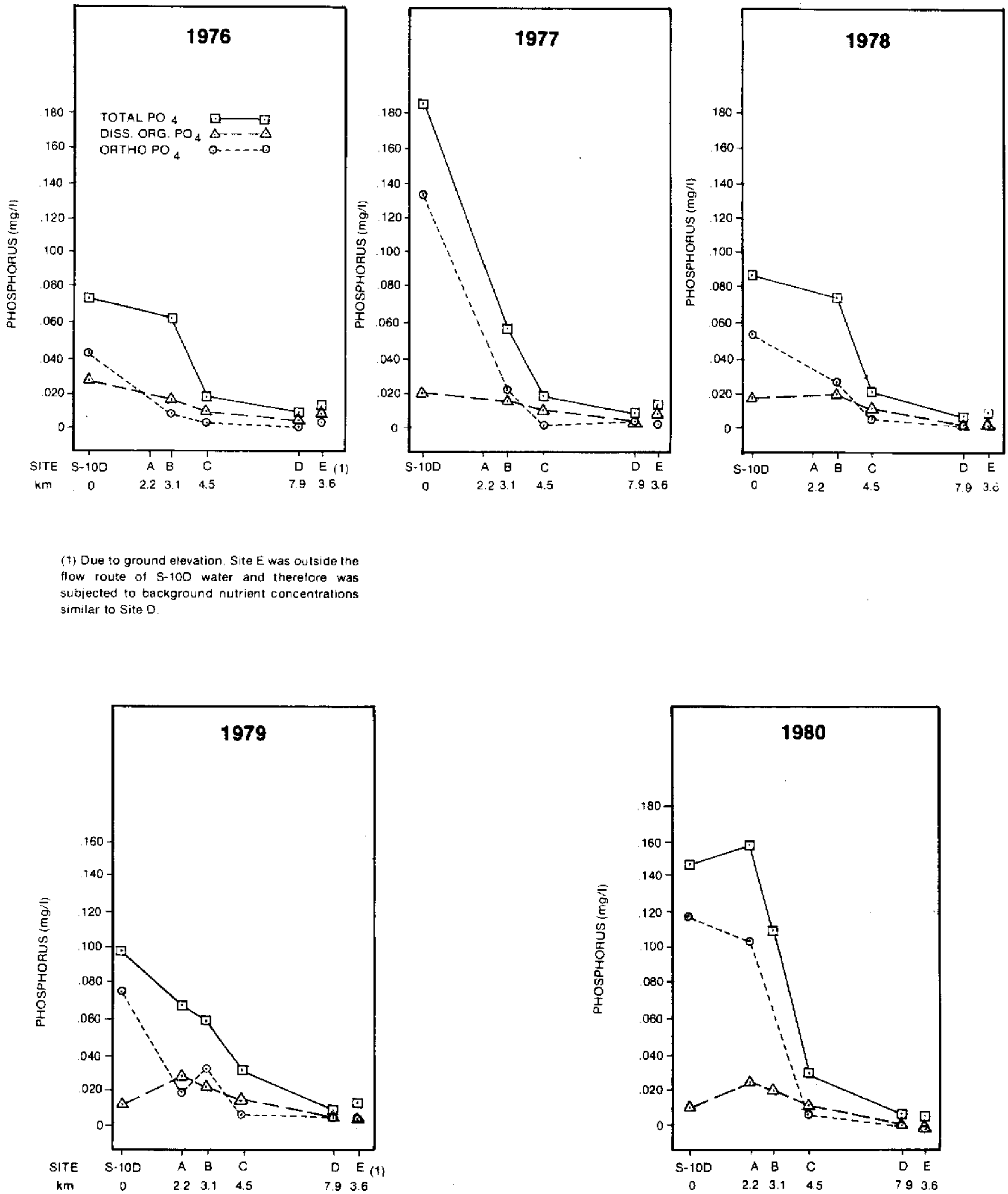


Figure 30 MEAN ANNUAL PHOSPHORUS CONCENTRATIONS (mg/l) IN SURFACE WATER IN WATER CONSERVATION AREA 2A IN RELATION TO DISTANCE (km) FROM INFLOW STRUCTURE S-10D.

distance south of the S-10D structure. Ortho-PO_4 represented the largest fraction of phosphorous in S-10D water. In contrast, dissolved organic PO_4 concentrations were relatively low in S-10 inflow water, and this fraction showed only small decreases in concentration at interior marsh sites.

Inorganic nitrogen (NO_3 + NO_2 + NH_4) concentrations in surface water also showed rapid declines from S-10D southward. The majority of N in S-10D water was dissolved organic N and showed little net change between S-10D and WCA 2A interior marsh sites. Declines in organic N accounted for the majority of N taken up by the marsh (Figure 29).

Estimates of the area of nutrient enrichment that may be expected to impact the Holeyland marsh are based on two methods. The first is derived from nutrient uptake studies conducted in WCA 2A. This is simply the distance from a point of inflow that nutrients exist above background levels. In WCA 2A this distance was 4.5 km (2.8 miles) for ortho-PO_4 and inorganic N,, and 7.9 km (4.9 miles) for Total PO_4.

However, examination of Table 18 shows that nutrient loading to WCA 2A and the Holeyland are not equivalent (WCA 2A receives roughly 1.5-1.8 times as much P). The second method used was to correlate the average annual nutrient loadings into WCA 2A with the actual area impacted by nutrient enrichment. By use of aerial photography and water chemistry data collected from transect studies, this area was estimated to encompass approximately 6,000 acres in WCA 2A. On an annual basis, the WCA 2A marsh receives a mean Total PO_4 loading of 36.58 metric tonnes per year which impacts roughly 6,000 acres of Everglades marsh (after a period of 22 years). Transferring these relationships to the Holeyland, 16.2 tonnes Total PO_4 would impact an area of 2,600 acres in the vicinity of the east Holeyland pump, while 7.95 tonnes Total PO_4 would impact 1,300 acres of marsh adjacent to the west pump.

Predicted areas of nutrient enrichment in the Holeyland are illustrated in Figure 31. The distributions of the enrichment zones were based on the assumptions that sheetflow will occur during most pumping periods and that water will be evenly distributed from the point of pumping. The actual zone of nutrient impact area will depend to some degree on the alignment of interior canals.

Nutrient concentrations in the water flowing out of the Holeyland into WCA 3A should be similar to background concentrations in WCA 2A. Total PO_4, ortho-PO_4, and dissolved inorganic N concentrations should not exceed .010 mg/l. Dissolved organic N concentrations should range between 2.0 and 3.5 mg/l.

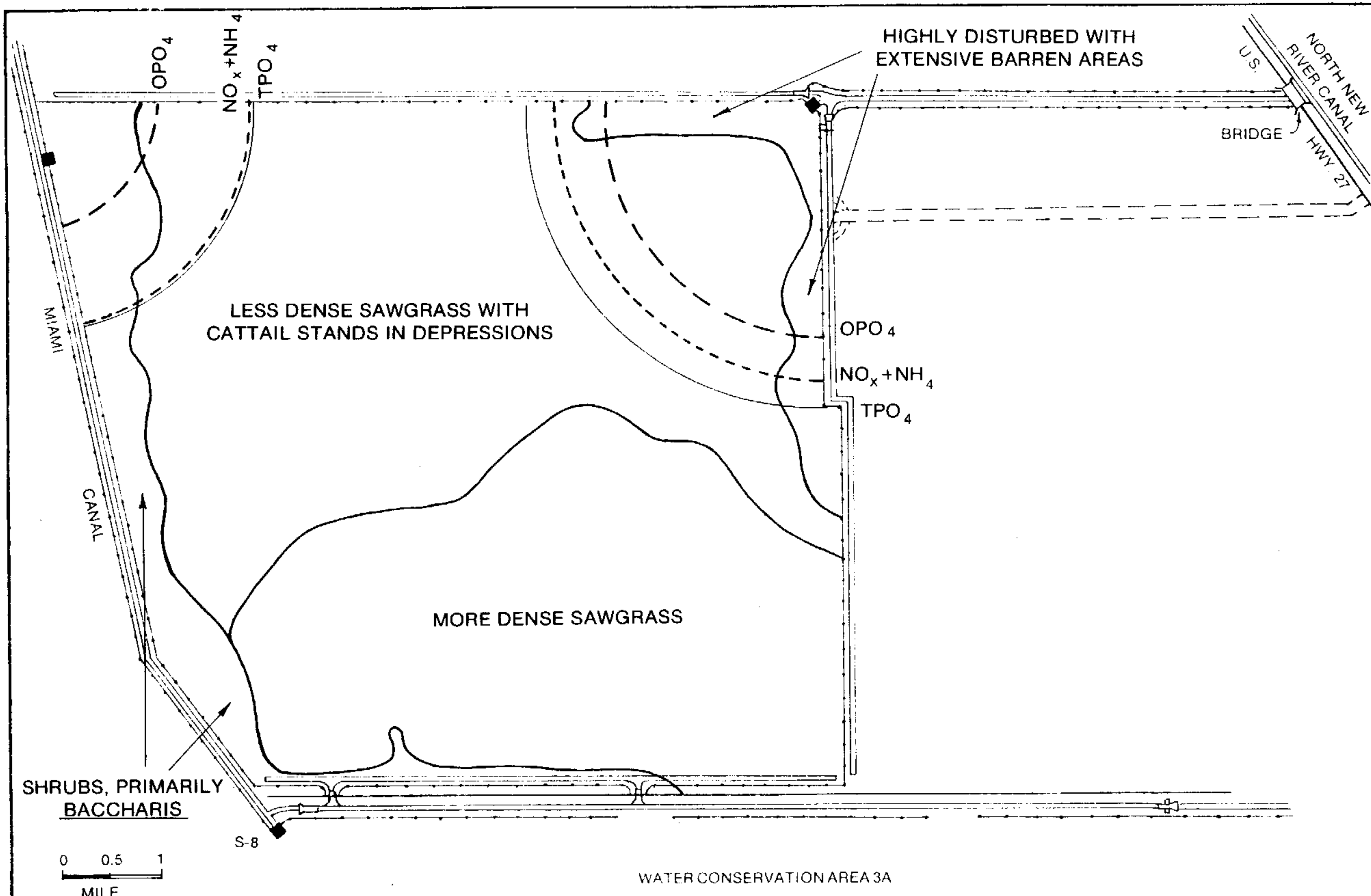


Figure 31 HOLEYLAND GENERALIZED MAP OF EXISTING VEGETATION WITH PREDICTED AREAS OF NUTRIENT ENRICHMENT.

3. Impacts on flora and fauna

Existing plant communities in the Holeyland

The existing vegetation in the Holeyland can be separated into four major plant communities (Figure 31).

The most highly disturbed area (approximately 2,000 acres) occurs adjacent to the levees in the northeast corner of the Holeyland. Much of this area was devoid of emergent vegetation when an aerial survey was made in January 1983. Fallen decomposing trunks of pig weed (*Amaranthus hybridus*) were common, and widly scattered shoots of cattail (Typha sp.) were emerging between them. Extensive pockets of exposed bedrock in this area apparently resulted from peat fires.

A 3,000 acre shrub area dominated by saltbush (Baccharis sp.) borders the west and south levees. Stands of large red maple (*Acer rubrum*) and wax myrtle (*Myrica certifera*) are scattered among the saltbush. Numerous trails from track vehicles crisscross this area. Water hyacinths (*Eichhornia crassipes*) were observed in the depressions left by the tracks.

Sawgrass (*Cladium jamaicense*) still predominates in most of the interior marsh of the Holeyland. The sawgrass interior can be divided into a northern sector characterized by a greater degree of disturbance and a southern sector which appears less disturbed. In the northern area of approximately 15,500 acres, the sawgrass stand is less dense than in the southern area and is intermixed with herbaceous species (such as dog fennel (Eupatorium sp.)) characteristic of drained areas. Cattail stands grow in depressions which are scattered over the interior of the less dense sawgrass area. A matrix of trails from track vehicles also covers this area.

The southern portion of the interior sawgrass stand is characterized by a more dense growth of sawgrass with few other species present. This area (approximately 11,000 acres) apparently has been less affected by the impacts of drainage and fire.

Analysis of different water schedules (two, three, and four foot schedules) for Holeyland

All of the computer runs of three and four foot schedules, either variable ascending or flat, indicate the same general environmental effect in the Holeyland. Some of the predictable environmental effects are as follows:

a. A shift toward a bladderwort/white water lily slough-oriented aquatic system encroaching within the existing sawgrass community.

b. Sawgrass will be maintained and will probably compensate for increased inundation by tussock formation as found in the deeper portions of WCA 2A.

c. Periphyton species changes and increases in biomass of periphyton.

d. Sufficient drying periods to prevent a build-up of deep layers of unconsolidated organic materials (1967, 1971, 1974, 1975 and 1981).

e. A water level conducive to wading bird feeding in the January through April time frame in most years.

f. At times, good to excellent sport and pan fishing will occur as a result of the Holeyland retaining some water during the spring months. During the 19-year period of the routings, each of the three and four foot schedules contain five events when water is retained on the marsh through one or more consecutive dry periods. The three and four foot flat schedules, as well as the four foot variable schedule, each indicate one long wet period of 33 consecutive months within the time period analyzed and will offer rather spectacular fishing. The three foot variable schedule does not indicate the 33 month inundated period but does indicate five periods of 20 month flooding.

g. Alligators may be common in the Holeyland under any of the three and four foot schedules, but nesting and reproduction will be extremely limited due to the rapidity with which the waters rise during the June through September nesting season.

h. A loss of woody vegetation can be anticipated. Flooding on an annual basis to depths of three and four feet will eventually drown the trees. Most of the woody vegetation is not growing on elevated sites (tree islands) as it is in the Water Conservation Area system.

i. Hyacinths will grow in the open areas nearest the pump stations. Hyacinths will not do well outside of the zone of nutrient enrichment.

j. Period of inundation and depth of water which will act adversely on the woody vegetation will offer favorable conditions for a large population of apple snails (Pomacea). These two factors together will act as an enhancement to the Everglade Kite, which will use the Holeyland as a feeding area on an annual basis and as a nesting area during the time period the trees are water-stressed.

k. There will be no huntable deer herd in the Holeyland.

l. There will be an increase in cattails in the enriched zone affected by the pumps.

Analyses of the computer runs for the two foot schedule led to the following conclusions:

a. Bladderwort/white water lily will exist but will not dominate anywhere other than present ponds.

b. Sawgrass will be maintained in its present condition.

c. Periphyton species changes and increases in periphyton biomass will also take place with the two-foot schedules, as these are functions of wate chemistry.

d. Sufficient drying periods will occur to prevent build-up of deep layers of unconsolidated organic materials (1965, 1967, 1968, 1971, 1973, 1974, 1975, 1976, and 1981).

e. Declining water levels conducive to wading bird feeding will occur in the December through March time frame in most years.

f. Fishing will not be as good as under the three and four foot schedules. There are only two periods during the 20-year period of projection which indicate a holdover of the sport fish population to age class II. Sport fishing will be fair on an annual basis for yearling bass.

g. Alligators may be fairly common in the Holeyland under the two foot water schedules, but nesting occurs during the time of the two-foot rise in water level, thus only very limited reproduction can be anticipated.

h. The woody vegetation presently in the Holeyland will probably be maintained.

i. Hyacinths will grow on an annual basis but will not do well outside the pumped zone of enrichment.

j. Water depths and duration of flooding are not conducive to <u>Pomacea</u> snail production or Everglade Kite use.

k. There will be no huntable deer herd in the Holeyland.

l. There will be an increase in cattails in the enriched zone affected by the pumps.

<u>Rotenberger area impacts</u>

At the request of District staff, the Florida Game and Fresh Water Fish Commission provided a general assessment of the impacts of the District's proposal for the Rotenberger area, which is provided below. The complete transmittal is included in the Appendix, along with a detailed historical tabulation of game harvest levels for the Rotenberger area, Holeyland, Brown's Farm, and Everglades Wildlife Management Areas.

"Relatively little is known about Rotenberger topographic relief and no previous Everglades habitat restoration projects have been undertaken. We cannot, therefore, project future wildlife populations and wildlife harvest as a result of more water. However, we expect that deer populations and deer harvest will be lower under a

0- to 1-foot schedule than under the hydrologic conditions of recent years and perhaps significantly so.

"Most deer on the Rotenberger WMA occur in the northern one-half of the area. If the lands between the Manley Ditch and the Rotenberger Township were excluded from the restoration project and subsequently developed for economic purposes, the deer herd would be severely reduced, and this impact would be most unwelcome.

"The 0- to 1-foot schedule you propose should be favorable to the development of wet prairie communities that provide valuable waterfowl winter habitat, and waterfowl populations should increase. Wetter conditions should also provide more snipe and other shorebird habitat. Numerous wading birds, including the endangered wood stork, will be afforded favorable feeding conditions due to the increased hydroperiod. Longer hydroperiods should also benefit marsh nesting wildlife species such as gallinules, waterfowl, rails, bitterns, alligators, and various passerine birds by providing more attractive and predictable nesting conditions.

"Practically any reasonable schedule should encourage the development of woody vegetation on the higher portions of the area through reduction of destructive fires. Hopefully, some of the tree islands that have been burned out of the area will be reestablished. Reestablishing tree islands will increase vegetation diversity and provide improved habitat for a wide range of Everglades wildlife.

"The District's 0- to 1-foot schedule is acceptable as an interim schedule for the restoration of Everglades habitat on the Rotenberger WMA. However, depending on vegetation and wildlife community response to this schedule, schedule alteration (including possible increases) may be appropriate, even obligatory, in the future. Consequently, structural features should accommodate higher regulation schedules and water levels which may result from abnormally heavy precipitation.

"An important point we want very much to stress is that restoration of Everglades habitat in the Rotenberger was a prime consideration at the time of acquisition and we are aware of no change in that intent. While your letter emphasized the impacts of water on game and game harvests, it is important to stress that a diversity of Everglades wildlife, in general, will benefit from restoration efforts. While some species will decline, others will increase and hopefully, a proper balance can be struck. That is why it is important to retain flexibility on the matter of water schedules."

D. Impacts on Regional Water Management System

1. Irrigation recycling

None of the plans analyzed have the capability to meet all of the irrigation water requirements of the Miami and the North New River Canal basins. Simulated results show that different plans can normally supply between 58,000 and 113,000 AF per year of the local requirement, depending upon the schedule chose. An additional foot of water storage in the Holeyland area increased the recycling water available for irrigation by 21,000 to 25,000 AF/year under the flat schedule and approximately 17,500 to 21,200 AF/year under the fluctuated schedule. The flat schedule would provide more water than the fluctuated schedule (8,700 AF/year under a 2-foot maximum and 16,500 AF/year under a 4-foot maximum). This difference occurred primarily during the dry season when more water was projected to be available under the flat schedule (see Table 19). The recycled water from the Rotenberger area under the 2 foot schedule was projected to be 6,500 AF/year for the area bounded by the Deer Fence Canal extension and 10,800 AF/year for the area including the Manley Ditch.

2. Flow to the Water Conservation Areas

Table 19 presents the summary of flow to WCA 3A and WCA 2A via pump stations S-8 and S-7 and gravity sheetflow to the northwest corner of WCA 3A. In general, a reduction of pumpage by S-8 and S-7 would result under increasing water storage in the Holeyland area; however, the pumpage at S-8 and S-7 is smaller under the flat schedule than under the fluctuated schedule. A substantial decrease in pumpage at S-7 and S-8 would result under the last two scenarios, due to increasing water storage in the Rotenberger area and additional pumpage during the wet season. Gravity sheetflow did not follow the same pattern, decreasing under the fluctuated schedule as compared to the flat schedule and increasing under the last two scenarios.

3. Impacts on regional water supply capabilities

The water shortage and operational changes brought about by the Holeyland plans will increase the overall urban and agricultural water supply capabilities and decrease the frequency and severity of supply shortfalls when compared to the Interim Action Plan. The resulting expected decrease in drought damages is a significant benefit of the Interim Action Plan. This section of the report provides an assessment of the impacts that the Holeyland plans will have on the frequency and severity of expected shortages and presents estimates of the drought damage reductions this would entail.

It is important to note that in this analysis the Holeyland reservoir is treated as an integral part of the C&SFFCP. Thus, while the Holeyland reservoir will be providing water directly to the Everglades Agricultural Area, the net system impact will be to increase the supply capabilities of other storage areas. this additional supply capability may be used to benefit agricultural or urban interests in either the Lake Okeechobee or Lower East Coast areas depending on the needs and priorities established at the time of need.

The first step in this process is to analyze the adequacy or inadequacy of system supply capabilities under the Interim Action Plan. The chief indicator used to measure this capability was the minimum total available water storage for Lake Okeechobee and the Water Conservation Areas for each of the hydrologic years (November to

TABLE 19

SUMMARY OF AVERAGE ANNUAL TOTAL FOR IRRIGATION RELEASES, S-8, S-7 AND GRAVITY SHEETFLOW TO WCA 3A UNDER PROPOSED SCENARIOS, UNIT IN AF

Scenario	Irrigation Releases		Total	Flow to WCA 3A by S-8	Flow to WCA 3A by S-7	Gravity Flow to WCA 3A
	Wet Season	Dry Season				
Holeyland 2 ft. flat	27,076	39,807	66,883	141,451	116,513	102,208
Holeyland 3 ft. flat	30,851	61,465	92,316	127,535	98,157	100,141
Holeyland 4 ft. flat	33,523	79,740	113,263	120,459	94,750	79,570
Holeyland 2 ft. fluctuated	20,272	37,867	58,139	149,080	127,407	93,156
Holeyland 3 ft. fluctuated	21,000	58,344	79,344	139,601	115,619	85,672
Holeyland 4 ft. fluctuated	21,917	74,891	96,808	131,375	114,355	69,609
Holeyland-Rotenberger 2 ft. fluctuated	18,769	45,822	64,591	113,541	107,469	117,083
Holeyland-Rotenberger 2 ft. fluctuated[1]	18,879	50,054	68,933	102,425	108,541	113,101
Historical[2]	76,460[3]	146,975[3]	222,435[3]	202,792	136,029	0

[1]Area includes Manley Ditch

[2]Prior to Lake Okeechobee TOP; backpumping to Lake Okeechobee through S-2 and S-3 in effect

[3]Releases from Lake Okeechobee

October) from 1964 to 1981. This is defined as the estimated total water supply available for release from Lake Okeechobee and the three Water Conservation Areas. The quantities calculated represent storage above stages of 9.2 feet NGVD for Lake Okeechobee and 10.0, 7.0, and 6.0 feet NGVD for WCA 1, 2, and 3, respectively.

These data, presented in Table 20, show that in three and possibly four of the 18 years the system supply capabilities would be in serious question. Under conditions of low storage, such as those estimated for 1964-1965 and 1980-1981, the declaration of a water shortage and the requiring of use reductions would be an appropriate management strategy in order to avoid even more serious damages later should the system storage become fully depleted. In the case of negative storage (1973-1974), all demands will not be able to be met even if this were the management strategy being followed. For instance, in 1974 the estimated accumulated demands not met by the day of minimum storage (May 31, 1974) was 73,500 cubic feet.

For purposes of further analysis, a minimum storage level of 400,000 acre feet will be used to divide situations requiring water use cutbacks from those which do not. Thus, the lowest three years under the Interim Action Plan are considered those under which a water shortage declaration would take place.

A system indicator which tends to confirm the interpretations made of the system storage levels is the stage in Lake Okeechobee. In the three worst years, the minimum stage in the lake was below 10.5 feet. In the fourth year, it was close but slightly above 10.5 feet. In the other years, it was above 11 feet.

The next step is to estimate the additional supplies which would be available as a result of the holeyland storage areas. To do this, storage differences were calculated for the days on which minimum storage occurred as presented in Table 20. These data are presented in Table 21. The storage differences refer only to Lake Okeechobee and the three Water Conservation Areas because the Holeyland is not a major factor is system storage at low points since it will be the first priority source of irrigation water for the Everglades Agricultural Area.

Storage differences are presented as an average for both the three years when minimum storage was the lowest and for the full 18 years covered in the analysis. This was because while the performance of the Holeyland plans under low water conditions was of primary concern, an examination of the data indicated that the measured performance of the Holeyland plans in the years of concern depended more on the situation as the year began than on what took place during the year of low water conditions.

The data indicate that all the Holeyland plans provide significant additional storage. The pattern also emerges that the higher and the steadier the schedule, the greater the contibution. It is interesting

TABLE 20

IN SYSTEM STORAGE UNDER THE INTERIM ACTION PLAN
(IN RANK ORDER)

YEAR	DATE OF MINIMUM STORAGE	MINIMUM STORAGE (ACRE FEET)
1968-1969	6/4/69	3,008,000
1979-1980	7/15/80	2,728,000
1969-1970	5/23/70	2,707,000
1978-1979	7/10/79	2,120,000
1965-1966	5/21/66	1,739,000
1966-1967	6/2/67	1,713,000
1971-1972	4/28/72	1,483,000
1967-1968	5/7/68	1,310,000
1977-1978	6/18/78	1,225,000
1974-1975	5/11/75	1,000,000
1975-1976	4/30/76	872,000
1970-1971	6/6/71	720,000
1963-1964	4/24/64	636,000
1976-1977	5/3/77	623,000
1972-1973	6/6/73	438,000
1964-1965	6/6/65	283,000
1980-1981	7/17/81	125,000
1973-1974	5/31/74	-20,000[1]

[1]At this time there had also been an accumulated total of 73,500 AF of demands not met.

TABLE 21

ADDITIONAL STORAGE AVAILABLE
AS A RESULT OF THE HOLEYLAND PLANS

	ADDITIONAL SYSTEM STORAGE (ACRE FEET)	
HOLEYLAND PLAN	AVERAGE FOR EIGHTEEN YEARS	AVERAGE FOR LOWEST THREE YEARS
3 feet flat	288,000	228,000
4 feet flat	332,000	297,000
3 feet fluct.	241,000	157,000
4 feet fluct.	290,000	210,000
2 feet fluct.	173,000	87,000
2 feet fluct. (to Manley Ditch)	187,000	93,000

to note (from a separate model run) that the four foot flat schedule on average restores almost as much storage to the system as would the elimination of backpumping restrictions (332,000 versus 358,000 acre feet). Furthermore, it provides a higher minimum storage for the 18-year period (327,000 acre feet in 1965 versus 209,000 in 1981).

The value of additional water supplies in years when water use is restricted has been estimated by the District at $250 per acre foot for situations in which the cutback levels are mild and properly managed[1]. This value is associated with impacts such as the slowing of growth of sugar cane and pasture, the changing of lawn watering schedules to inconvenient hours and the forced reduction of domestic inside water use. This same value has also been selected for use in this analysis.

For each Holeyland plan, dollar benefit estimates for the additional water supplies were next formulated using the estimated additional storage for that plan for each of the three years when additional storage would be of benefit. Any amount of the additional storage which would raise total system storage above 400,000 acre feet was not credited since it was thought that this would extend the storage above that needed to avoid a water shortage declaration. The total credited additional storage for the three years was multiplied by the estimated $250 per acre foot value and divided by 18 to put the analysis on an annual basis. These estimated annual water supply benefits are presented in Table 22 along with a present value sum of this annual benefit over a period of 20 years. This latter value is especially useful if it is desired to compare the water supply benefits of the Holeyland plans to their costs. The 20-year period was selected to correspond with average expected life of Holeyland capital improvements. A discount rate of 10 percent per annum was used in estimating the present value of future benefits.

4. Water deliveries to Everglades National Park

As can be seen in Table 23, the average monthly discharges to the ENP, estimated by the simulation model, do not appreciably change with the management alternatives evaluated, but they are between 10 to 23 percent higher than historical. The Interim Action Plan alternative will result in higher annual discharges to the Park than any of the Holeyland alternatives, but the higher discharges will occur during the wet season months (June-November).

5. Water quality impacts on Everglades National Park

Both the IAP and the various Holeyland options for water management in the EAA result in substantially increased discharges of water to ENP because of increased discharges to WCA 3A. The source of this additional water is, of course, the stormwater runoff from the S-2 and S-3 drainage basin that are no longer pumped into Lake Okeechobee.

[1]South Florida Water Management District, An Analysis of Water Supply Backpumping for the Lower East Coast Planning Area, February 1982, p. 50.

TABLE 22

ESTIMATED AGRICULTURAL AND MUNICIPAL WATER SUPPLY BENEFITS OF THE HOLEYLAND PLANS

HOLEYLAND PLAN	ANNUAL EXPECTED VALUE OF BENEFITS	20 YEAR PRESENT VALUE OF EXPECTED BENEFITS
3 feet flat	$ 9,698,000	$ 82,569,000
4 feet flat	10,516,000	89,533,000
3 feet fluct.	7,548,000	64,264,000
4 feet fluct.	9,058,000	77,120,000
2 feet fluct.	4,646,000	39,556,000
2 feet fluct. (to Manley Ditch)	4,905,000	41,761,000

TABLE 23

MONTHLY AVERAGE DISCHARGES TO ENP (Ac-Ft)

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Interim Action	37,718	28,311	29,607	18,924	21,717	36,120	59,317	71,858	95,819	115,137	97,068	53,675	665,271
Holeyland 4' Flat Plan	35,438	26,015	27,011	16,472	18,819	30,322	48,374	58,484	83,161	108,091	89,882	51,512	593,581
Holeyland 2' & Rotenberger 2' Fluctuation Schedules including Manley Ditch	35,372	26,007	28,456	17,604	19,801	31,984	50,136	59,640	84,292	108,817	90,372	52,134	604,615
Historical	25,052	24,608	30,104	23,562	17,409	35,525	56,981	65,952	76,684	80,714	64,767	39,749	541,108

Since the IAP has already been utilized as an operational criterion in the EAA from July 1979 to June 1981, the direct, short-term impacts of this alternative can be evaluated using monitoring data collected during that time period. Unfortunately, during the second half of this period, South Florida was entering into a prolonged drought. It is generally felt that the drought adversely affected ambient water quality conditions so that direct comparison of water quality conditions during the IAP to a controlled period of normal rainfall are complicated by this drought factor. In this evaluation, the two years immediately preceding the drought (July 1977 to July 1979) were chosen as the control period.

The Holeyland options result in slightly less water but of superior quality, being discharged to WCA 3A compared to the amount of discharge for the IAP. The IAP, therefore, is the "worst case" situation as far as potential impacts to the ENP are concerned.

Any potential impacts that might occur under the Holeyland options can be interpreted as being somewhere between IAP and present conditons.

The specific objectives of this section is to determine if any changes can be detected in the quality of the water entering Everglades National Park during the IAP.

The underlying hypothesis is that the water quality at the S-6, S-7, and S-8 pumping stations will decline due to the influence of poorer quality runoff from the S-2 andS-3 basins. This poorer quality water will be passed through the WCA 3A and subsequently delivered to the Everglades National Park through the 12 structures.

For comparative purposes, data from pump station S-8 and the S-12D structure are utilized in this evaluation. The S-12D structure is the easternmost of the four S-12 structures which pass water from WCA 3A to ENP. It is located very close to the terminus of the L-67A canal which is directly connected to the Miami Canal and S-8 pumping station. These two stations, S-8 and S-12D, represent the most direct hydraulic link between the EAA and the ENP; and therefore, it is most probable that any potential water quality impact due to increased pumping at the southern end of the EAA would be most evident as S-12D.

General Water Quality

Average values for eight common water quality parameters measured at the S-8 pump stations and the S-12D discharge structure for the two year IAP period (7/79-6/81) and a comparison "normal" period (7/77-6/79) are shown in Table 24. These data were collected by the District as part of two separate water quality studies within the Water Conservation Area system. Samples were collected on a biweekly frequency at the S-12D structure and by an automatic flow proportional sampler at the S-8 pump station. District reports on both of these studies are currently in preparation.

TABLE 24

MEAN VALUES FOR SELECTED WATER QUALITY PARAMETERS AT S-8 AND S-12D DURING IAP AND NORMAL OPERATIONS

Parameter	Period: IAP 7/79-6/81	Period: Normal 7/77-6/79	ENP Std.
Specific Conductance (micromhos/cm)	$\frac{896}{738}$	$\frac{796}{654}$	647
Dissolved Oxygen (mg/L)	$\frac{5.6}{4.3}$	$\frac{5.6}{4.2}$	4.5
pH units	$\frac{7.62}{7.38}$	$\frac{7.42}{7.21}$	7.6-8.0
Total Phosphorus (mg/L P)	$\frac{0.044}{0.014}$	$\frac{0.050}{0.012}$	0.24
Ortho Phosphorus (mg/L P)	$\frac{0.015}{0.003}$	$\frac{0.013}{0.004}$	0.02
Total Nitrogen (mg/L N)	$\frac{3.87}{2.50}$	$\frac{2.88}{1.95}$	2.9
Ammonia (mg/L N)	$\frac{0.07}{0.04}$	$\frac{0.06}{0.02}$	0.24
Nitrate (mg/L N)	$\frac{0.895}{0.150}$	$\frac{0.609}{0.115}$	0.7

KEY: $\frac{\text{S-8 Value}}{\text{S-12D Value}}$

It is evident from Table 24 that despite the relative direct hydraulic connection between S-8 and S-12D via the Miami and L-67A canals, the water quality at S-12D is substantially different than the water quality at S-8 for both time periods. With the exception of dissolved oxygen, all parameters indicate that the quality of water at the S-12D structure is superior to the quality at the S-8 pump station.

The percent reduction in specific conductance, a conservative parameter, between S-8 and S-12D was about 20 percent for both periods. By contrast, the percent reductions in the various nutrient species ranged from about 35 percent for total nitrogen to 85 percent for nitrate nitrogen. Dilution with water of lower conductance including rainwater is the most likely mechanism for the reduction in specific conductance. The much greater reductions in the nutrient parameters which are affected by biological processes indicate that biological mechanisms as well as dilution are probably responsible for those trends. The magnitude of these reductions as well as the ambient concentrations measured at S-12D are consistent with the results of nutrient uptake studies in WCA 2A and WCA 3A discussed elsewhere in this report.

Comparisons of water quality parameters at S-8 and S-12D during and before the IAP indicate that all parameters had increased values during the IAP with the exception of dissolved oxygen and total phosphorous at S-8. With the possible exception of the increase in the average total nitrogen concentration, the magnitude of these increases are probably not statistically or environmentally significant and may be due either to the influence of poorer wate quality from the S-3 drainage basin being pumped south or to the impact of the drought conditions on general wate quality throughout South Florida. Dissolved oxygen showed no change at S-8 and a 0.1 mg/L increase at S-12D. The average total phosphorous concentration decreased by 0.006 mg/L during the IAP at S-8 but increased by 0.002 mg/L at S-12D.

The water quality standards established by the January 1979 Memorandum of Agreement between the Corps of Engineers, Everglades National Park, and the District are also shown in Table 24. These standards are applied to the annual average quality of water entering the Park via the S-12 structure. As can be seen in the table, none of the annual averages for the nutrient parameters at S-12D exceed these standards. The pH and dissolved oxygen standard is exceeded for both periods while the specific conductance standard is exceeded only during the IAP.

Trace Metals

A substantial amount of data are available on the concentrations of various trace metals in the water entering the ENP. The Corps of Engineers has collected seven (7) samples in the L-67A canal just upstream of S-12D since January 1980 as part of their ENP Water Quality Monitoring program, while the District has collected five (5) samples for trace metal analysis at the S-12D structure since 1978. The results of the analyses for eight (8) trace metals common to these two monitoring programs are summarized in Table 25.

TABLE 25

SUMMARY OF TRACE METAL DATA AT L-67A/S-12D

	As	Cd	Cr	Co	Cu	Pb	Zn	Hg
Oct. 1978 1/	-	1	1	1	1	1	29 6/	-
Feb. 1979 1/	-	1	1	1	1	1	31 3/	-
				IAP				
Aug. 1979 1/	-	1	1	-	4	5	21	-
Jan. 1980 2/	2	0.5	2	2	2	3	8	0.2 4/
February 1980 1/	-	1	1	-	3	1	22	-
April 1980 2/	1	2 5/	6	2	6	2	5	1.62 6/
July 1980 2/	2	0.6	2	2	2	2	14	0.2 7/
Aug. 1980 1/	-	1	-	1	5	5	21	-
Oct. 1980 2/	2	0.5	2	2	5	2	6	3.5 6/
Jan. 1981 2/	2	0.5	2	2	3	2	17	0.1
April 1981 2/	7	0.5	4	18 8/	7	2	12	0.2 7/
July 1981 2/	6	0.5	4	1	2	1	1	0.1

1/ SFWMD data

2/ COE data

3/ Potentially exceeds Florida State Standard of 30 micrograms/L

4/ Exceeds ENP Std. of 0.5 micrograms/L

5/ Exceeds Florida State Standard of 1.2 micrograms/L

6/ Exceeds ENP Standard of 0.5 micrograms/L

7/ Potentially exceeds Florida State Standard of 0.1 microgram/L

8/ Exceeds ENP Standard of 5 micrograms/L

Unfortunately, only two of the 12 sampling dates occurred prior to the IAP so the effect that the IAP may have had on the trace metal concentrations is difficult to determine by direct comparison. In addition, the low concentrations of these elements and high degree of difficulty associated with their analysis results in relatively large analytical uncertainties within these types of data.

With the exception of one zinc value that may be 1.0 microgram/L above the Florida State Standard for Class III waters of 30 microgram/L, the two samples collected prior to July 1979 indicate no concern for trace metal pollution in the water at the S-12D structure.

After July 1979 measurable amounts of all eight metals were detected either at S-12D or in L-67A. The most consistent "increase" appears to have occurred with respect to copper and lead although in either case were any values above either the State Standards for Class III waters or the ENP standards. One cadmium value was 2.0 micrograms/L which is above the State Standard of 1.2 microgram/L but well below the ENP standard of 10 microgram/L. Also, one cobalt value was above the ENP standard of 5 microgram/L. There is no State Standard for cobalt. In both cases, these two values appear to represent outliers and are not representatiave of any general trends.

All but two of the mercury values exceed either the State Standard of 0.1 microgram/L or both the State and ENP Standard of 0.5 microgram/L. These high mercury values were initially of great concern to the ENP, Corps, and District. However, investigations by the Corps of Engineers laboratories indicate that the two highest values may be the result of mercury contamination of the sample bottles.

In addition to the data in Table 25, the District also collected samples for trace metals analysis at the S-8 pump stations on the same dates indicated in Table 25. These samples were analyzed for cadmium, chromium, copper, lead, and zinc. The results of these analyses substantiate to a degree the trends noted for the S-12D/L-67A data. Concentrations of cadmium, chromium, and zinc were low, both before and after the IAP. However, higher values for copper and lead were measured at S-8 after July 1979. In the case of lead, two of the samples exceed the ENP Standard of 8 micrograms/L.

Pesticides

Three separate monitoring programs have generated data on the level of pesticide and herbicide residues in the general area of interest for this evaluation.

On four occasions (10/72, 4/73, 10/73, and 10/74), the District collected sediment samples at the S-8 pump station and had them analyzed for selected chlorinated hydrocarbon pesticides. Of the nine compounds tested for, as indicated in Table 26, positive results were indicated for only two. PCB's were detected in all five samples, but there is some indication that the levels have substantially decreased from 10/72 (400 micrograms/Kg) to 10/74 (15 micrograms/Kg). Trace amounts (0.1 microgram/Kg) of Dieldrin were detected in the 10/73 sample.

TABLE 26

PARAMETER COVERAGE FOR WCA-3A PESTICIDE MONITORING

Agency Date Station	SFWMD 12/24/80 WCA-3A (5 Sites)	Corps 1/80-4/81 L-67A	SFWMD 10/72-10/74 S-8
Aldrin	X	X	X
Chlordane	X	X	X
2,4-D	x		
DDD	x	x	
DDE	x	X	
DDT	X	X	X
Diazinon	X	X	
Dieldrin	X	X	X
2,4-DP	X		
Endosulfan	X	X	
Endrin	X	X	X
Ethion	X	X	
Ethyl Parathion	X	X	
Ethyl Trithion	X	X	
Heptachlor	X	X	X
Heptachlor Epoxide	X	X	
Lindane	X	X	X
Malathion	X	X	
Methoxychlor	X		
Methyl Parathion	X	X	
Methyl Trithion	X	X	
Mirex	X		
PCB Aroclor 1016	X	X	X
PCB Aroclor 1242	X		
PCB Aroclor 1248	X		
PCB Aroclor 1254	X		
PCB Aroclor 1260	X		
Perthane	X		
PCN Halowax 1000	X		
PCN Halowax 1099	X		
Silvex	X	X	
2,4,5-T	X	X	
Toxaphene	X	X	X

TABLE 27

CORPS OF ENGINEERS ENP
WATER QUALITY DATA - L-67A STATION
PESTICIDES/HERBICIDES

Parameter	Date 1/80	4/80	7/80	10/80	1/81	4/81	5/82
Aldrin	ND	0.040	ND	ND	ND	ND	35.7
Lindane	ND	ND	ND	ND	ND	ND	2.3
Chlordane	Trace	ND	ND	ND	ND	ND	52.5
DDD	ND	ND	ND	ND	ND	ND	0.19
DDE	ND	ND	ND	ND	ND	ND	0.15
DDT	ND	ND	ND	ND	ND	ND	11.6
Dieldrin	ND	ND	ND	ND	ND	ND	0.15
Endrin	ND	ND	ND	ND	ND	ND	0.20
Ethion	ND	ND	ND	ND	ND	ND	1.4
Toxaphene	ND	ND	ND	ND	ND	ND	2
Heptachlor	0.017	0.026	ND	ND	ND	ND	12.9
Heptachlor E	ND	ND	ND	ND	ND	ND	1.2
PCB	ND	ND	ND	ND	ND	ND	235.4 1/
Malathion	ND	ND	ND	ND	ND	ND	3
Parathion	ND	ND	ND	ND	ND	ND	1
Diazinon	ND	ND	ND	ND	ND	ND	1
Methyl Parathion	ND	ND	ND	ND	ND	ND	1
2,4,5-T	ND	ND	ND	ND	ND	ND	1.3
Silvex	ND	ND	ND	ND	ND	ND	4.1
Trithion	ND	ND	ND	ND	ND	ND	-
Methyl Trithion	ND	ND	ND	ND	ND	ND	-

1/80 - 3/81 Water samples. All results as microgram/L

5/82 Sediment sample. All results as microgram/Kg (dry weight)

1/ Aroclor 1016

In January 1980, the Corps began analyzing water samples collected in L-67A for a wide range of pesticides and herbicides as shown in Table 27. Of the six samples collected between 1/80 and 4/81, only two samples have shown positive results. The Heptachlor concentration was measured at 0.017 microgram/L in the 1/80 sample and at 0.026 microgram/L in the 4/80 sample. Dieldrin was measured at 0.04 microgram/L in the 4/80 sample. The Florida State Standards for Dieldrin and Heptachlor in Class III waters are 0.003 microgram/L and 0.001 microgram/L, respectively. Between 7/80 and 4/81, the Corps monitoring program did not detect any pesticide or herbicide residues in the water entering the ENP.

In December 1980 the District collected both sediment and water samples at five locations in WCA 3A (see Figure 32) and had these samples analyzed for a wide variety of pesticides and herbicides. The water samples had no detectable residues, but DDE (a metabolite of DDT) was detected in the sediments at all five locations while Chlordane was detected at four locations (all but station CA3-6) and Dieldrin at one location (station CA3-11).

In May 1982 the Corps collected a sediment sample at their L-67A monitoring station and had it analyzed for the same compounds that they tested their water samples for (see Table 27). The results of this analysis indicated that measurable residues of Aldrin (a percursor of Dieldrin), Chlordane, and Heptachlor were present in the sediments of the L-67A canal.

Unfortunately, there are no data available for the levels of pesticides and herbicides in the waters entering the ENP prior to the IAP so no "before" and "after" comparisons can be made. The best time series data are the Corps' data which indicates that there have been no detectable pesticide residues in the water since April 1980.

The compounds that have been detected in the water and sediments of WCA 3A have been highly restricted, if not banned, since the early to mid-1970's but were widely used prior to restrictions and are also highly persistent. Of the compounds detected, DDT and Dieldrin are no longer approved for use in the United States; and Aldrin, Chlordane, and Heptachlorare only approved for the control of subterranean termites. Therefore, the residues hat have been detected in the above-described samples undoubtedly reflect the affect of prior rather than current agricultural practices.

Since they are not agricultural chemicals, i.e., herbicides or pesticides, the presence of PCB's at the S-8 pump station and in the L-67A Canal is difficult to explain unless they are due to some local activity associated with the pump station. In any case, they do not seem to be present within WCA 3A, and their previously widespread use in industry has been greatly curtailed in recent years.

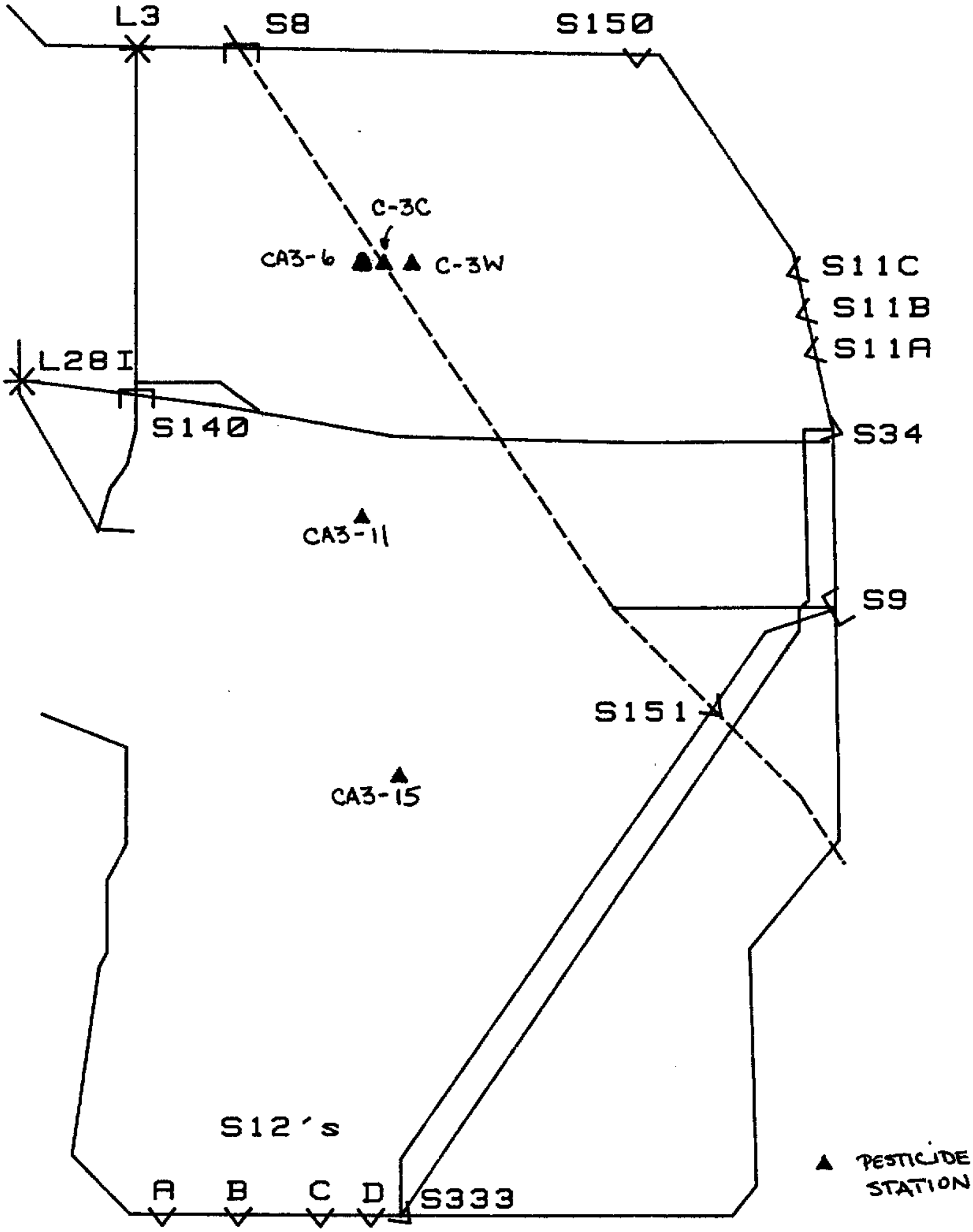


FIGURE 32

MAP OF WATER AND SEDIMENT PESTICIDE STATIONS IN WCA 3A

APPENDIX

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